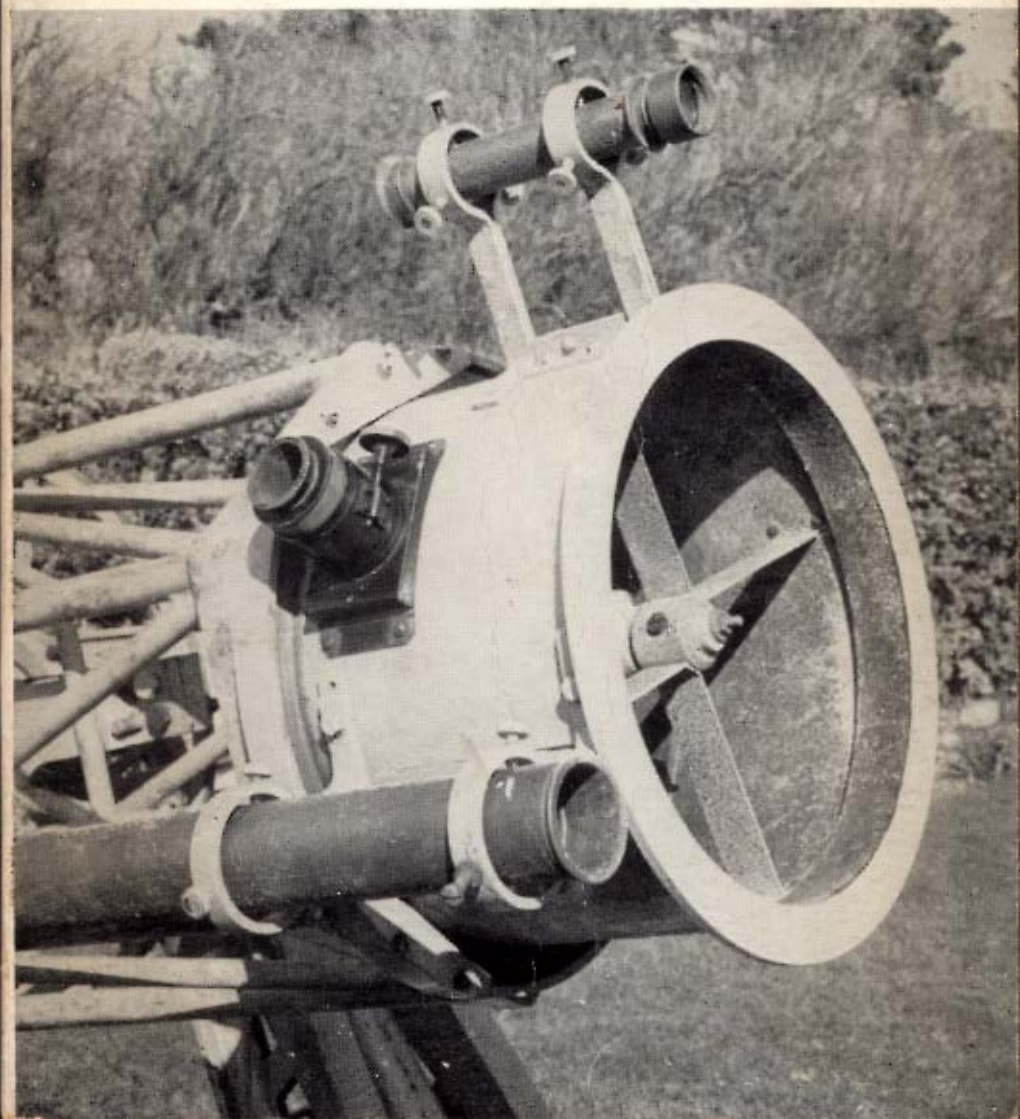
1965 Yearbook of Astronomy

Editor PATRICK MOORE



YEARBOOK OF ASTRONOMY 1965

EDITED BY
PATRICK MOORE

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Contents

Editorial · vii

PART I: EVENTS OF 1965

Notes on the Star Charts · 1

The Star Charts · 4–29

The Planets in 1965 · 30

Phases of the Moon, 1965 · 31

The Planets and the Ecliptic · 32

Notes on the Planets in the monthly diagrams · 33

Monthly Notes · 36–79

Eclipses, 1965 · 80

Occultations · 80

Comets in 1965 · 81

Meteors · 83

Minor Planets in 1965 · 84

Some Events of 1966 · 85

PART II: ARTICLE SECTION

Telescopic Faults · *G. A. Hole* · 87

Introduction to Mars · *Patrick Moore* · 101

Clouds in the Atmosphere of Mars · *S. Miyamoto* · 107

Meteoritic Craters · *Howard Miles* · 113

The Radio Sun · *F. W. Hyde* · 124

The Astronautical Outlook · *K. W. Gatland* · 134

Measuring the Universe · *Henry Brinton* · 144

Peculiarities among the Cool Stars · *Brian Warner* · 152

Recent Advances in Astronomy · *Patrick Moore* · 160

PART III: FOR STELLAR OBSERVERS

Some Interesting Telescopic Objects · 168

A Cycle of Clusters and Nebulæ · *James Muirden* · 170

PART IV: ASTRONOMICAL SOCIETIES

Notes on Astronomical Societies · 181

Some Recommended Books · 204

Editorial

With the 1965 issue of the *Yearbook*, we have a change of Editor. Dr J. G. Porter found that pressure of work did not allow him to continue in this capacity, and so, with some trepidation, I have stepped into his shoes. Dr Porter has, however, made vital contributions to the book, since he has – as before – provided almost all of Part One, including the star charts and the predictions for 1965 and excluding only the general notes at the end of each monthly section. It would have been very difficult, to say the least of it, to have produced this issue without him.

So far as the remainder is concerned, we have the usual Article Section and lists of interesting telescopic objects. However, there had been requests for something a little more detailed in the way of stellar observation, which is why we have included the 'cycle of clusters and nebulæ'; amateur work is so concentrated upon the Moon and planets that we sometimes tend to forget that the Solar System is a very small part of the universe. Notes on local (and national) astronomical societies have been expanded, again following numerous requests. This has meant the omission of the lengthy glossary of astronomical terms, but probably most people have now become familiar with these, and in any cases of doubt reference may be made to any of the previous *Yearbooks*.

I have received the utmost help and co-operation in editing this issue, and I am most grateful to Dr Porter, to the article authors, and to the publishers, with a special mention of Maurice Temple Smith of Messrs Eyre & Spottiswoode.

PATRICK MOORE

INDEX TO ARTICLES IN PREVIOUS *YEARBOOKS*

BAXTER, W. M. *Observing the Sun*: 1963.
BEET, E. A. *Astronomy as a Career*: 1963.
BRINTON, HENRY. *A Run-off Observatory*: 1963; *Astronomy and Navigation*: 1964.
CALVERT, H. R. *Astronomy at the Science Museum*: 1962.
CAMPBELL, D. A. *Astronomical Photography for Amateurs*: 1962.
CATTERMOLE, P. J. *Selenology: or Geology Applied to the Moon*: 1964.
DALL, H. E. *Eyepieces—a Practical Assessment*: 1963.
DE VAUCOULEURS, G. *Problems of Mars*: 1963.
FOX, W. E. *The Great Red Spot on Jupiter*: 1964.
GARSTANG, R. H. *The Structure of the Galaxy*: 1962.
GRIFFIN, R. *Automation in Astronomy*: 1962.
—*Variable Stars*: 1963.
HEY, M. H. *Meteorites and Life:* 1963.
JARRETT, A. H. *Recent Rocket Research*: 1962.
JENNISON, R. C. *Radio and Radar Astronomy*: 1962.
LAURIE, P. S. *Solar Research*: 1962.
—*Harrison, Maskelyne and the Longitude Problem*: 1964.
MILES, H. *With Mariner II to Venus*: 1964.
MOORE, PATRICK. *The Origin of the Universe*: 1962.
MURDIN, P. G. *Stellar Clusters*: 1963.
PEEK, B. M. *The Satellites of Jupiter*: 1962.
PORTER, J. G. *Astronomy and Space Research*: 1963.
—*The Distance of the Sun*: 1964.
RONAN, C. A. *Planetary Nebulae*: 1964.
—*The Distance of the Sun*: 1964.
VETTERLEIN, J. C. *Double and Binary Stars*: 1962.
WILDEY, H. *Telescope Mountings*: 1964.
WRIGHT, H. N. D. *The Surface of Saturn*: 1964.

PART ONE

Events of 1965

Monthly Charts and Astronomical Phenomena

Notes on the Star Charts

The stars, together with the Sun, Moon and planets, seem to be set on the surface of the celestial sphere, which appears to rotate about the Earth from east to west. Since it is impossible to represent a curved surface accurately on a plane, any kind of star map is bound to contain some form of distortion. But it is well known that the eye can endure some kinds of distortion better than others, and it is particularly true that the eye is most sensitive to deviations from the vertical and horizontal. For this reason the star charts given in this volume on pages 4 to 27 have been designed to give a true representation of vertical and horizontal lines, whatever may be the resulting distortion in the shape of a constellation figure. It will be found that the amount of distortion is, in general, quite small, and is only obvious in the case of large constellations such as Leo and Pegasus, when these appear at the top of the charts, and so are drawn out sideways.

The charts show all stars down to the fourth magnitude, together with a number of fainter stars which are necessary to define the shape of a constellation. There is no standard system for representing the outlines of the constellations, and triangles and other simple figures have been used to give outlines which are easy to follow with the naked eye. The names of the constellations are given, together with the proper names of the brighter stars. The apparent magnitudes of the stars are indicated roughly by using four different sizes of dots, the larger dots representing the bright stars.

There are four such charts at each opening, and these give a complete coverage of the sky up to an altitude of 62½ degrees; there are twelve such sets to cover the entire year. The upper two charts show the southern sky, south being at the centre; the coverage is 200 degrees in azimuth, from a little north of east

(top left) to a little north of west (top right). The two lower charts show the northern sky, from a little south of west (lower left) to a little south of east (lower right). There is thus an overlap east and west.

The charts have been drawn for a latitude of 52 degrees, but may be taken without appreciable error to apply to all parts of the British Isles. They will also be equally suitable for any other part of the world having a north latitude of about 52 degrees – e.g. parts of Europe and Asia, and Canada. In such cases the times given must be taken as local time, and not G.M.T., which applies only to the British Isles.

Because the sidereal day is shorter than the solar day, the stars appear to rise and set about four minutes earlier each day, which amounts to two hours in a month. Hence the twelve sets of charts are sufficient to give the appearance of the sky throughout the day at intervals of two hours, or at the same time of night at monthly intervals throughout the year. The actual range of dates and times when the stars on the charts are visible is indicated at the top of each page. This information is summarized in the following table, which gives the number of the star chart to be used for any given month and time.

G.M.T.	16^h	18^h	20^h	22^h	0^h	2^h	4^h	6^h
January	10	11	12	1	2	3	4	5
February		12	1	2	3	4	5	6
March			2	3	4	5	6	
April			3	4	5	6		
May			4	5	6	7		
June			5	6	7			
July			6	7	8	9		
August			7	8	9	10	11	
September		7	8	9	10	11	12	
October		8	9	10	11	12	1	
November	8	9	10	11	12	1	2	3
December	9	10	11	12	1	2	3	4

The charts are drawn to scale, and estimates of altitude and azimuth may be made from them. These values will necessarily be mere approximations, since no observer will be exactly on the meridian of Greenwich at 52 degrees latitude, but they will generally serve for the identification of stars and planets. The horizontal measurements, marked at every ten degrees, give the azimuths (or true bearings) measured from the north round through east (90 degrees), south (180 degrees), and west (270 degrees). The vertical measurements, similarly marked, give the altitudes of the stars up to 62½ degrees.

The ecliptic is drawn as a broken line on which the longitude is marked at every ten degrees; the positions of the planets at any time are then easily found by reference to the table immediately following the star charts on page 30.

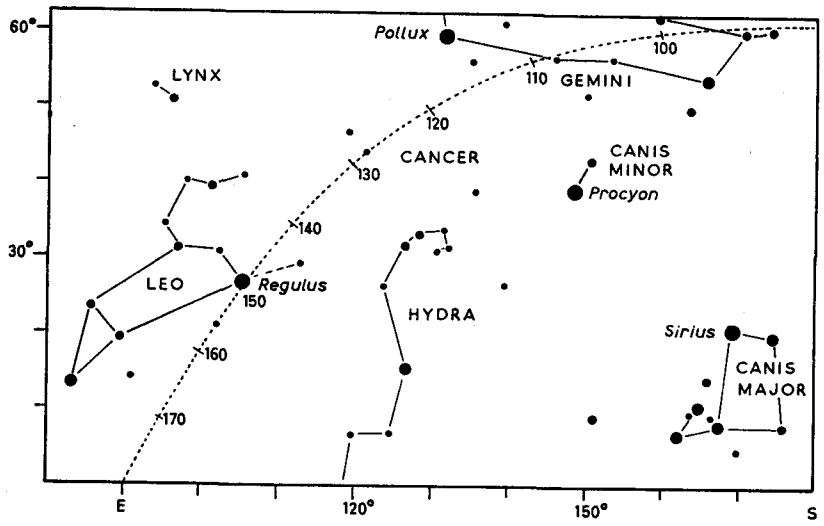
There is a curious illusion that stars at an altitude of 60 degrees or more are actually overhead, and the beginner may often feel that he is leaning over backwards in trying to see them. These high-altitude stars, being nearer the pole, move more slowly across the sky, and a different kind of map may therefore be used. These overhead stars are given separately on pages 28 and 29, the entire year being covered at one opening. Each of the four maps shows the overhead stars at times which correspond to those of three of the main star charts. The position of the zenith in latitude 52 degrees is indicated by a cross, and this cross also marks the centre of a circle which is 35 degrees from the zenith, and which therefore indicates an altitude of 55 degrees; there is thus a small overlap with the main charts.

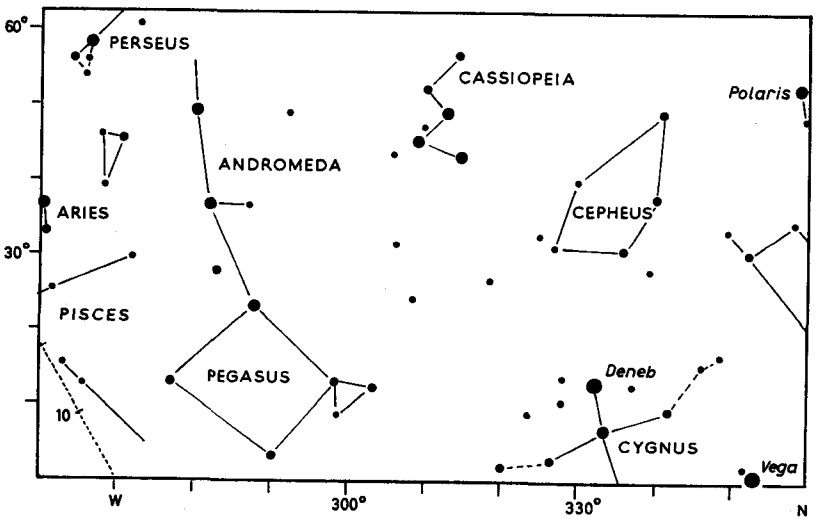
The broken line leading from north to south is numbered to indicate the corresponding main chart. Thus on page 28, the N-S line numbered 6 is to be regarded as an extension of the S line of chart 6 on pages 14 and 15, and at the top of these pages are given dates and times which are appropriate.

The scale is the same on all the charts (approximately 25 degrees to the inch), but the overhead stars are plotted as a true map on a conical projection, and are not simple graphs like the main charts.

1L

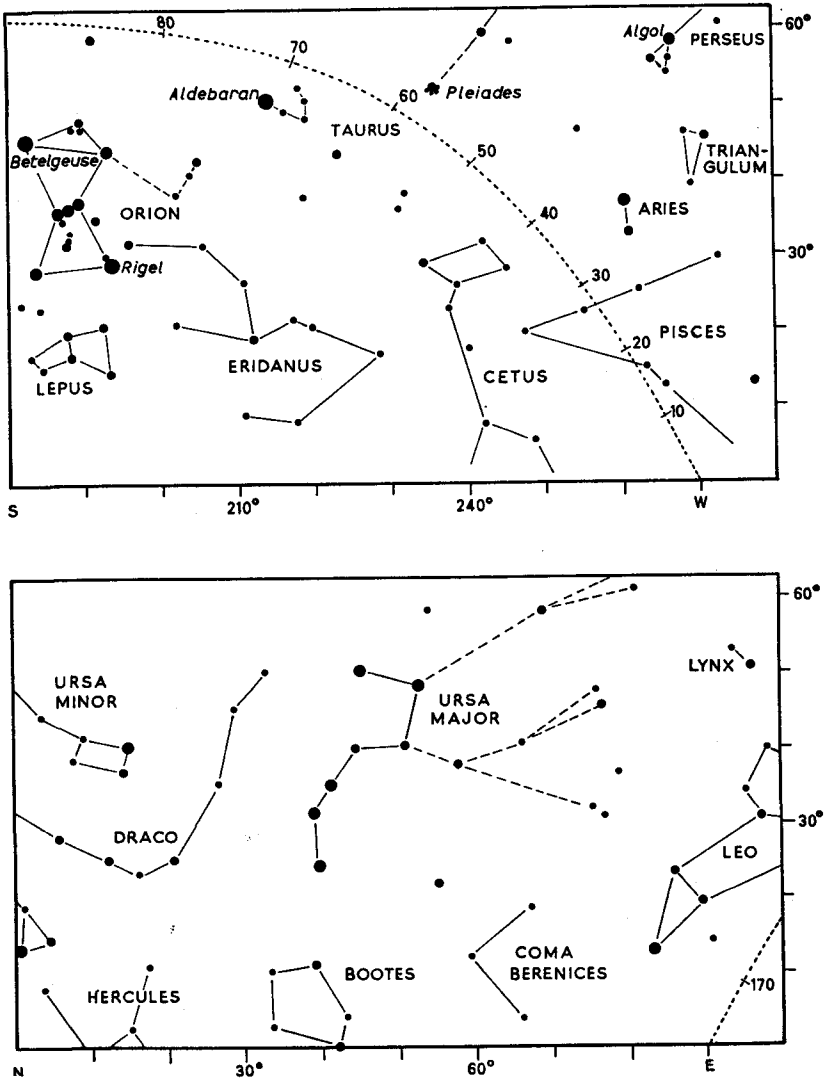
October 6 at 5h	October 21 at 4h
November 6 at 3h	November 21 at 2h
December 6 at 1h	December 21 at midnight
January 6 at 23h	January 21 at 22h
February 6 at 21h	February 21 at 20h





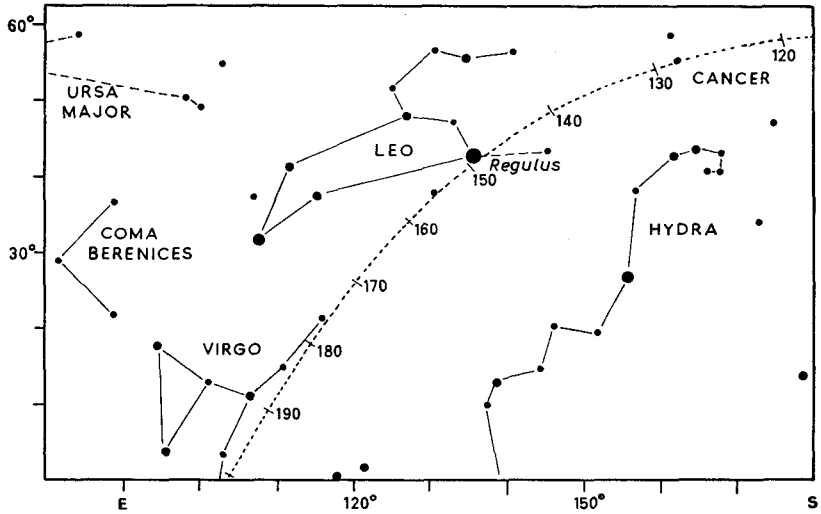
October 6 at 5^h	October 21 at	4^h
November 6 at 3^h	November 21 at	2^h
December 6 at 1^h	December 21 at	midnight
January 6 at 23^h	January 21 at	22^h
February 6 at 21^h	February 21 at	20^h

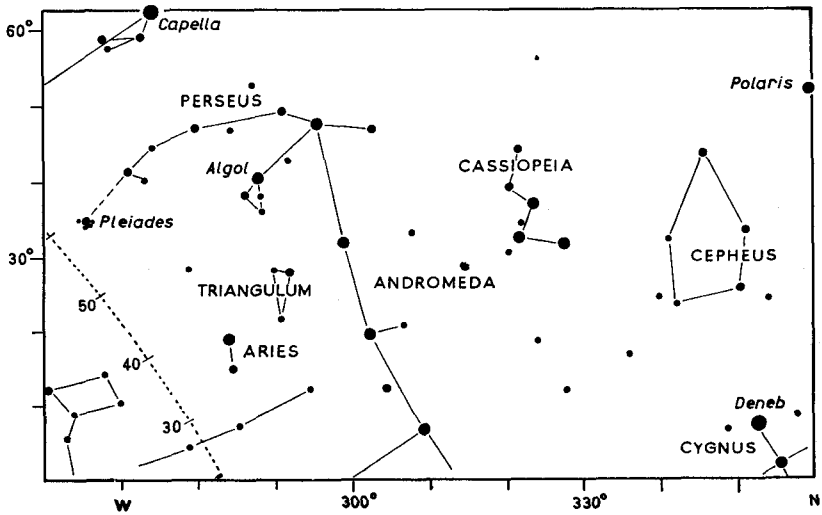
1R



2L

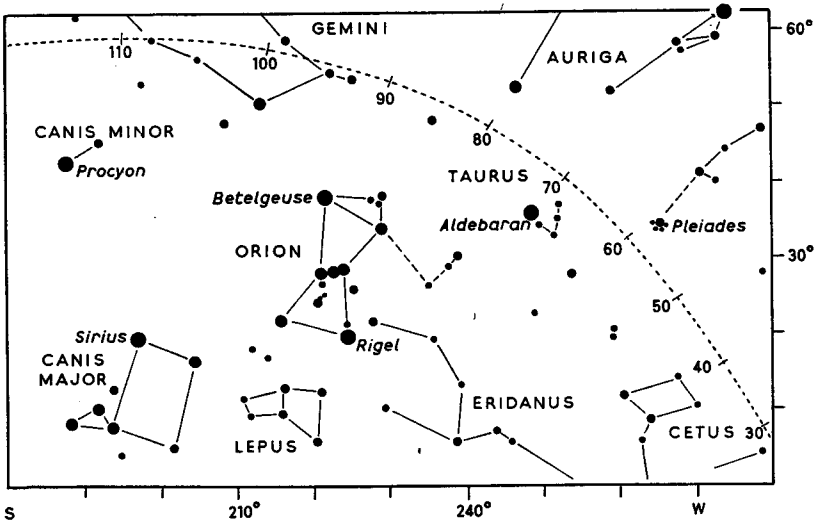
November 6 at	5^h	November 21 at	4^h
December 6 at	3^h	December 21 at	2^h
January 6 at	1^h	January 21 at	midnight
February 6 at	23^h	February 21 at	22^h
March 6 at	21^h	March 21 at	20^h

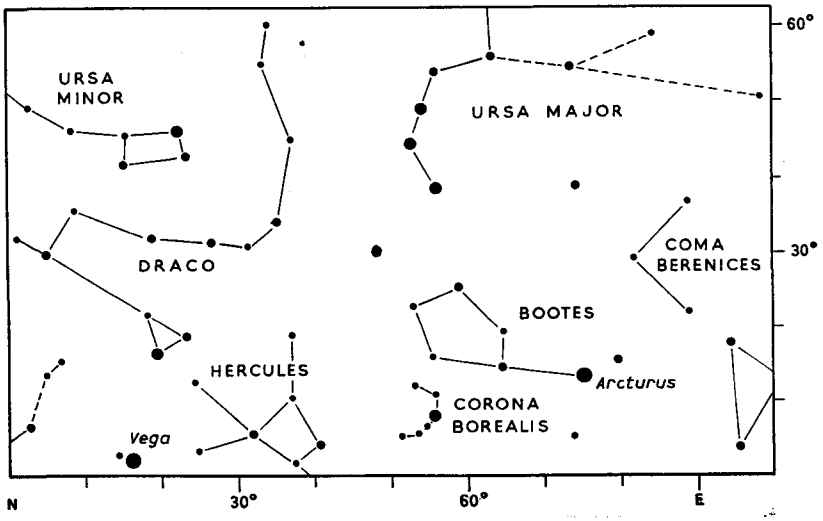




November 6 at	5h	November 21 at	4h
December 6 at	3h	December 21 at	2h
January 6 at	1h	January 21 at	midnight
February 6 at	23h	February 21 at	22h
March 6 at	21h	March 21 at	20h

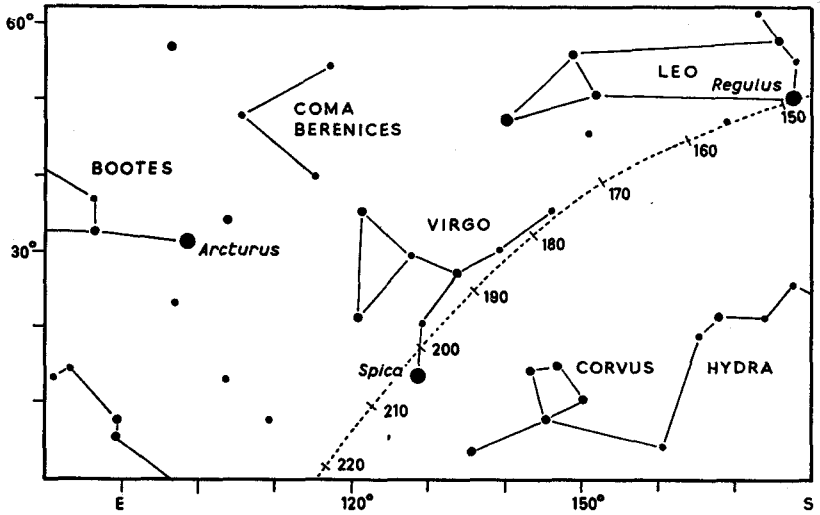
2R

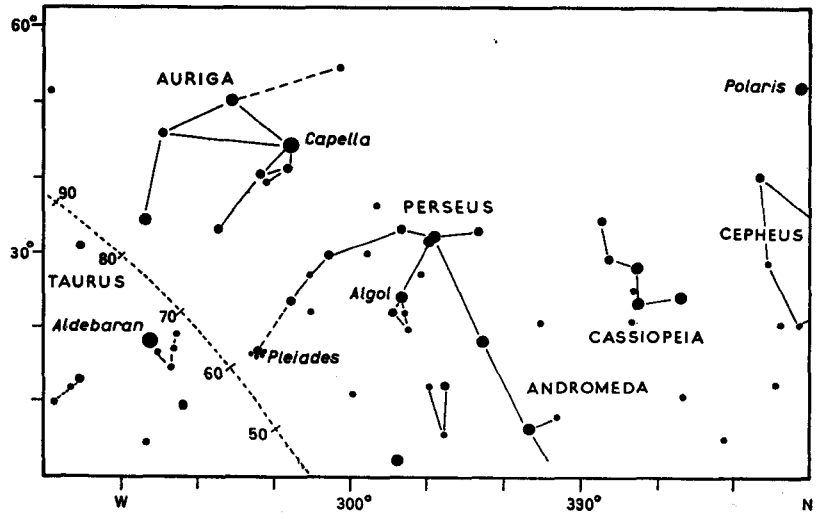




3L

December 6 at 5h	December 21 at 4h
January 6 at 3h	January 21 at 2h
February 6 at 1h	February 21 at midnight
March 6 at 23h	March 21 at 22h
April 6 at 21h	April 21 at 20h





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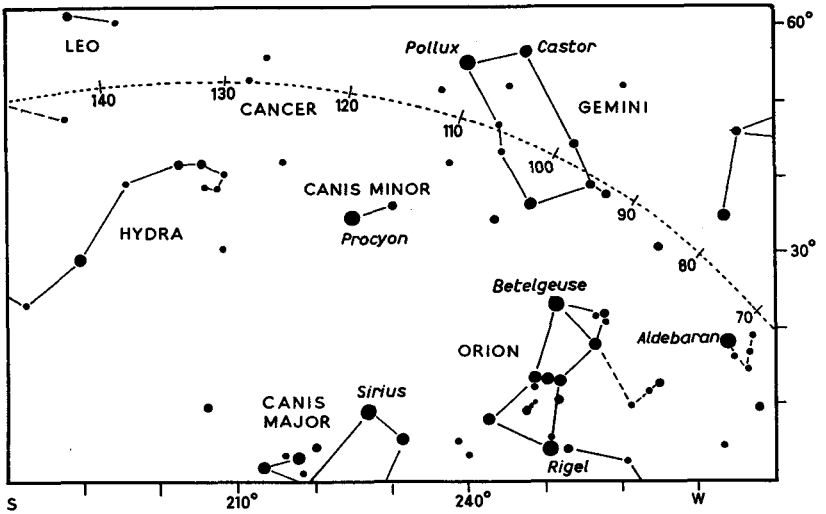
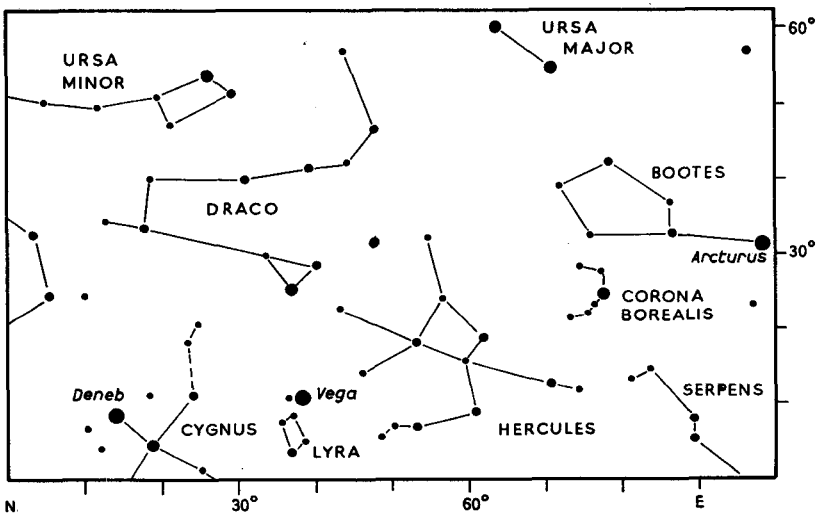
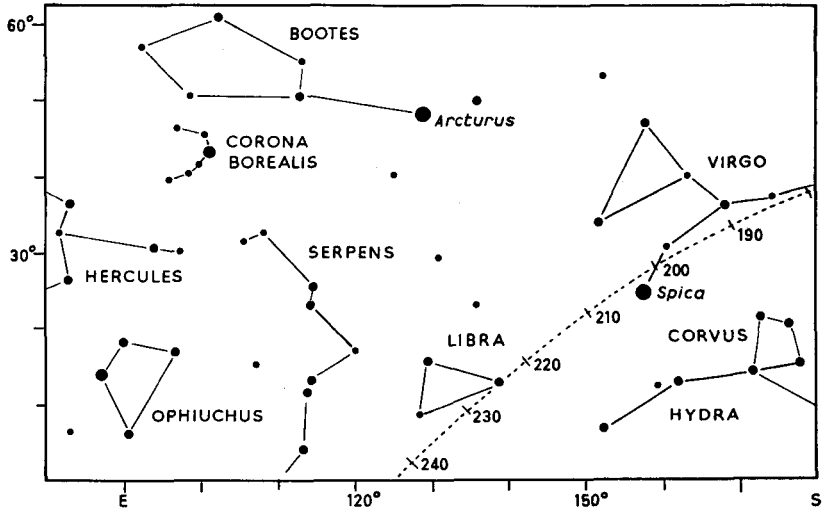
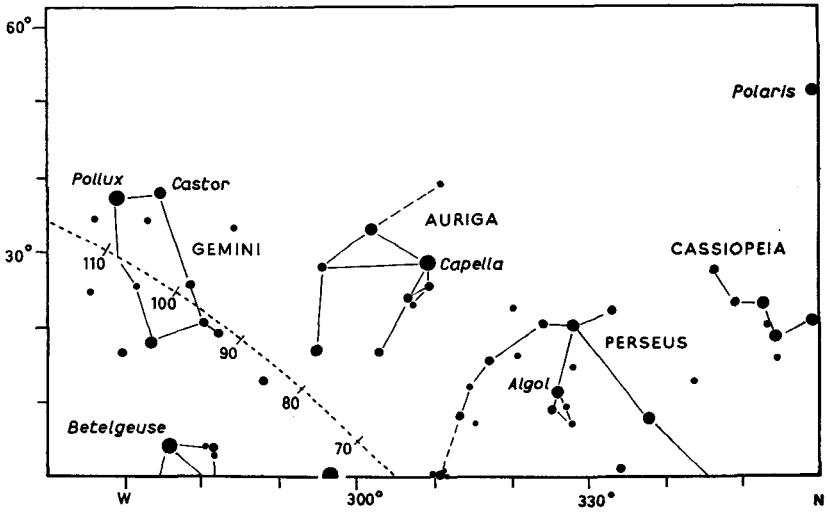




4L

January 6 at	5^h	January 21 at	4^h
February 6 at	3^h	February 21 at	2^h
March 6 at	1^h	March 21 at	midnight
April 6 at	23^h	April 21 at	22^h
May 6 at	21^h	May 21 at	20^h





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April 6 at 23h	April 21 at 22h
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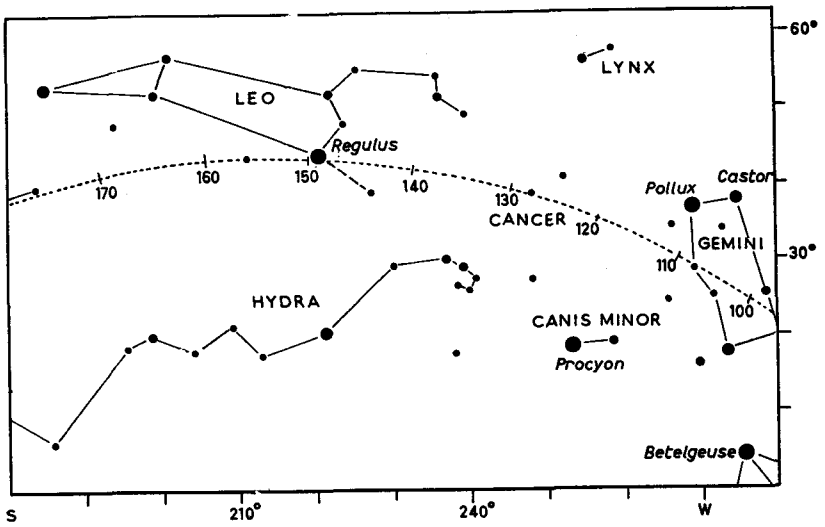

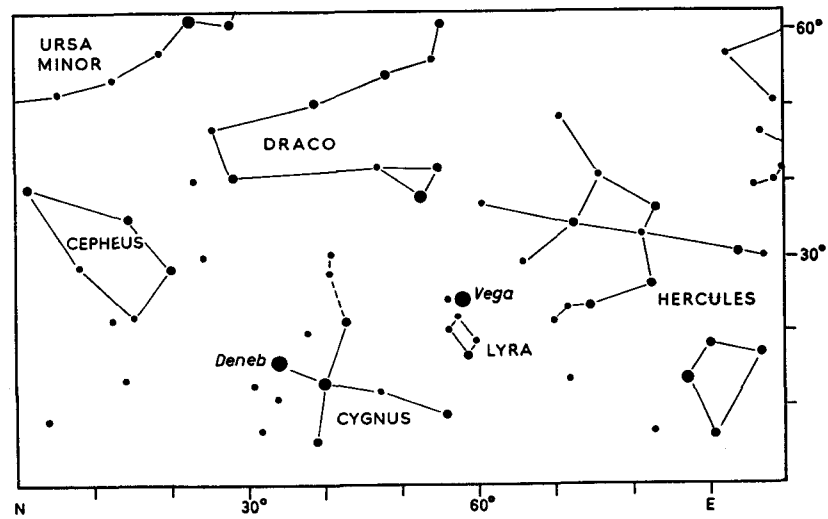

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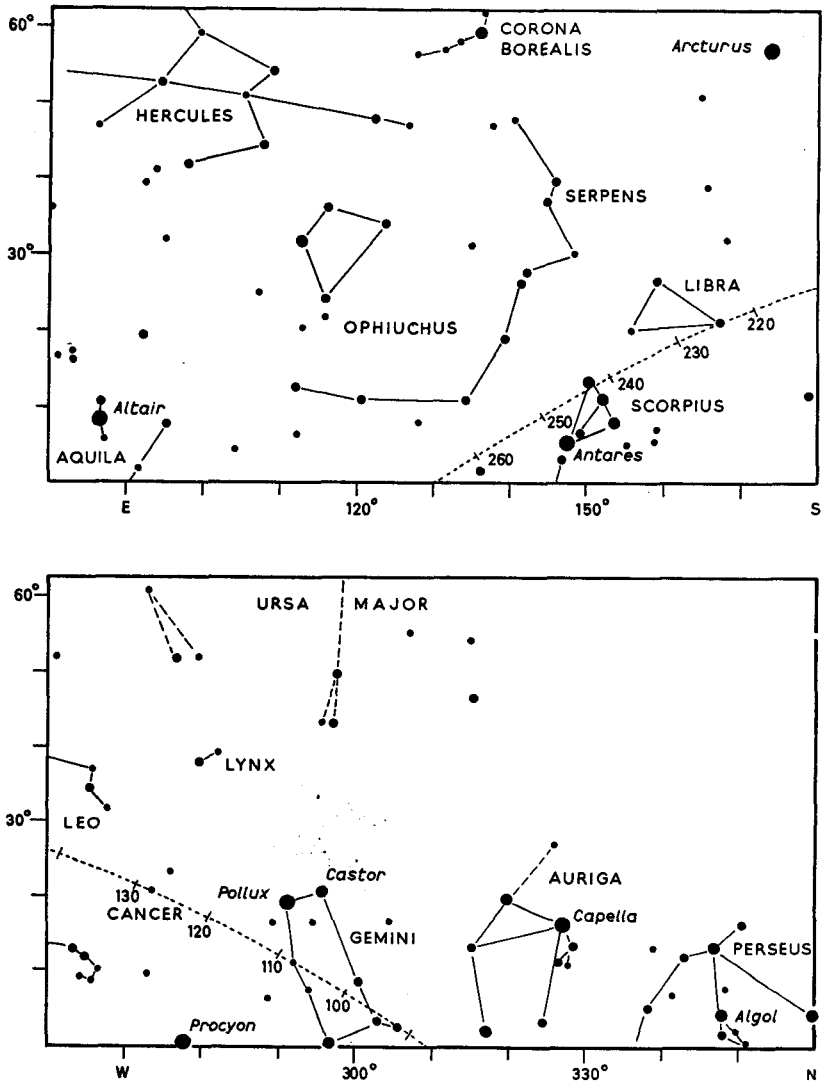

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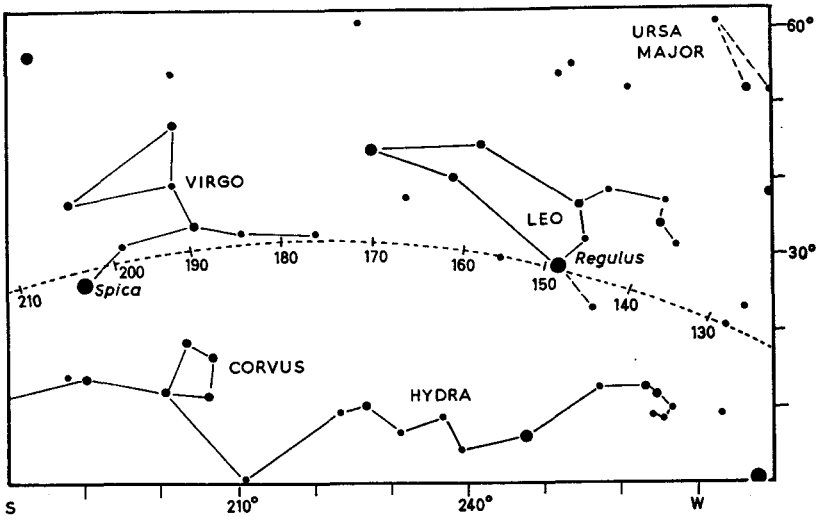

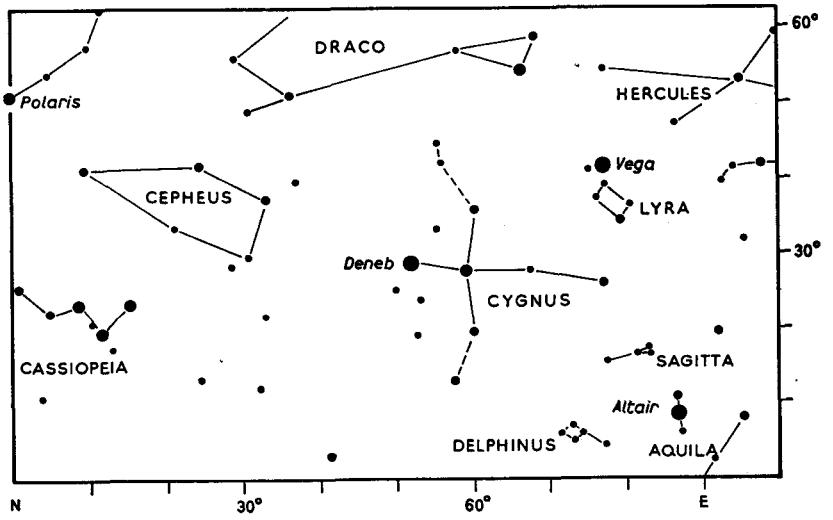

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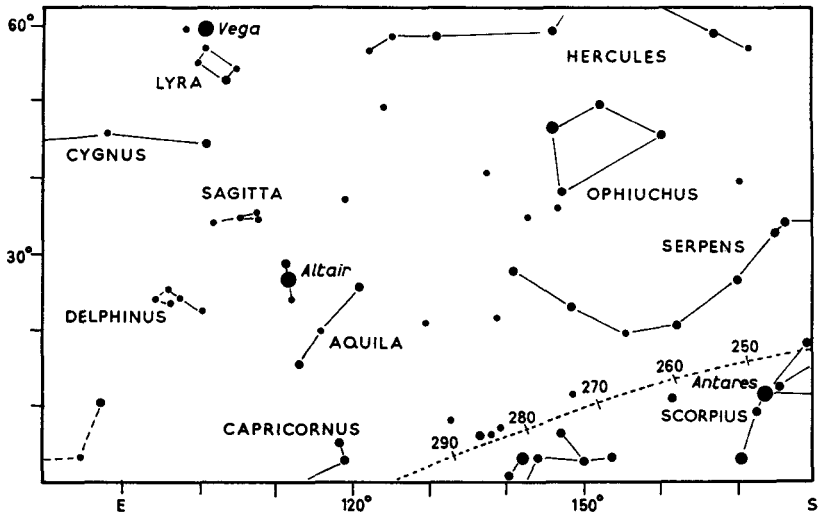

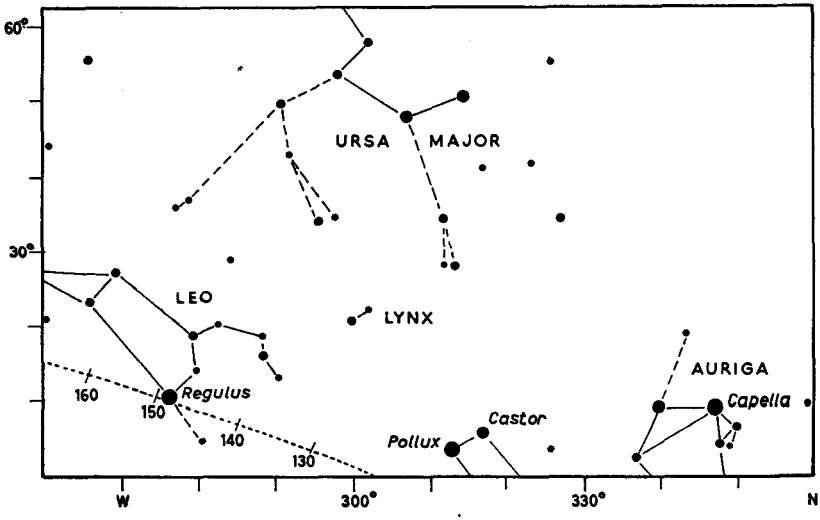

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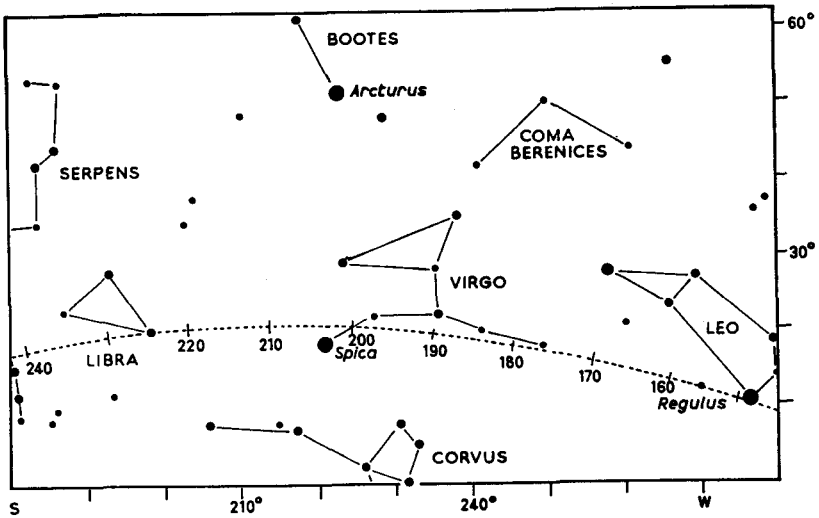

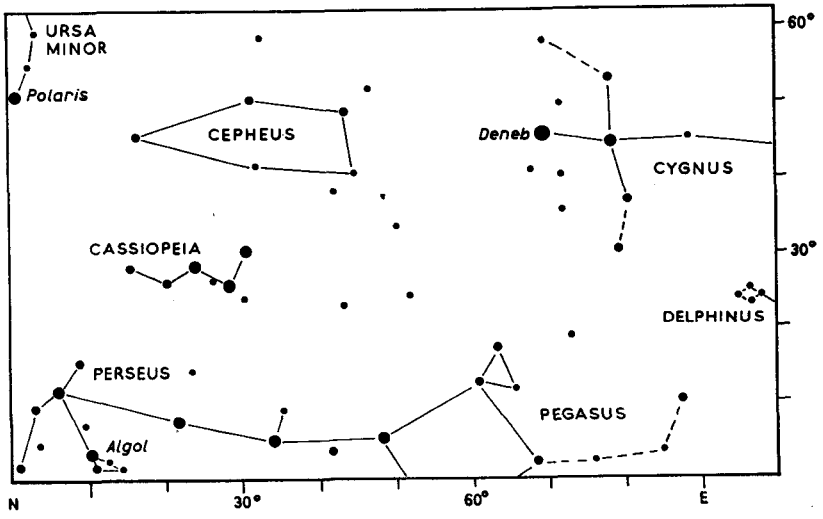

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May 6 at 3h	May 21 at 2h
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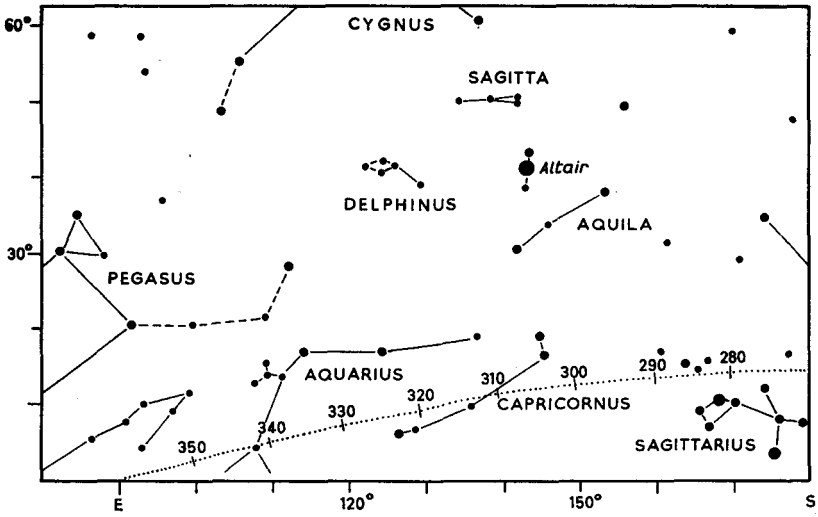
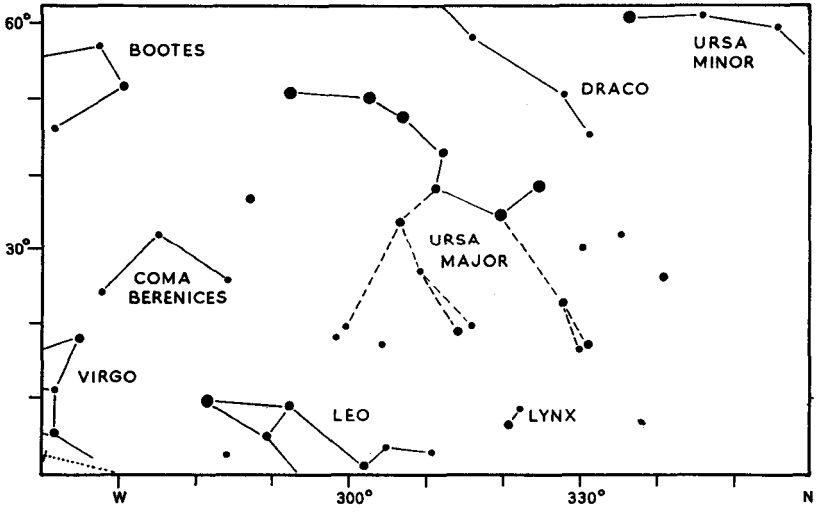
July 6 at 23h	July 21 at 22h
August 6 at 21h	August 21 at 20h
September 6 at 19h	September 21 at 18h





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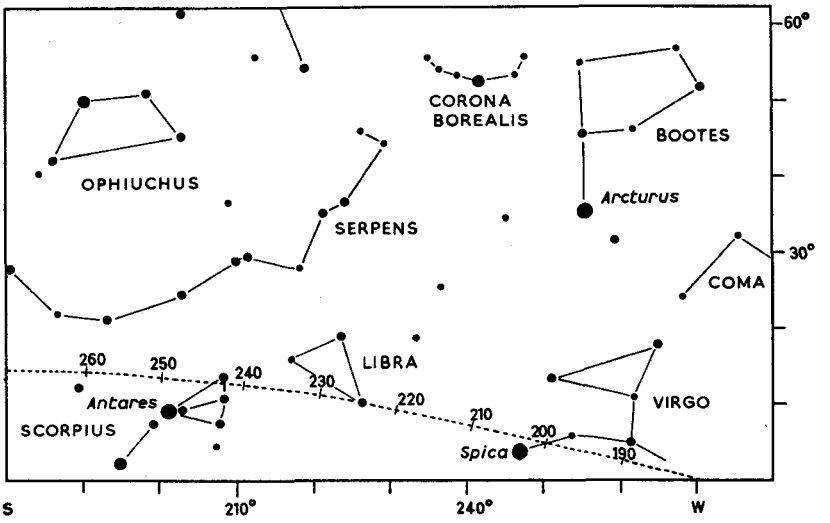

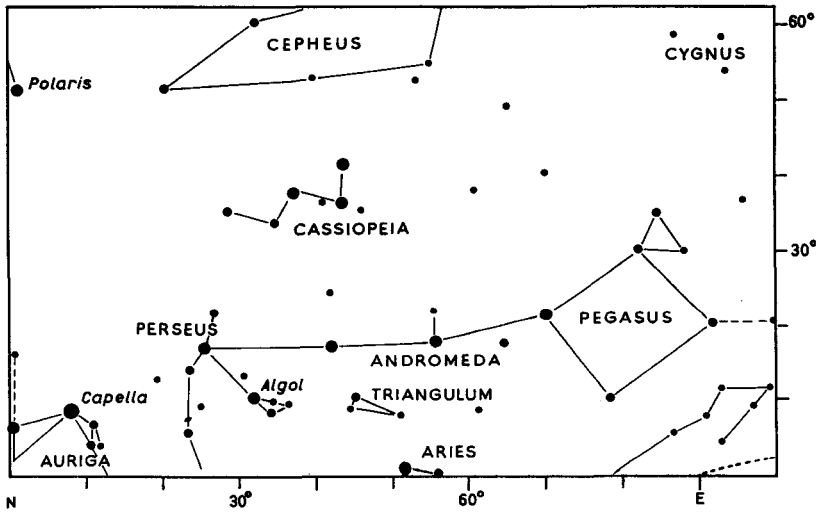

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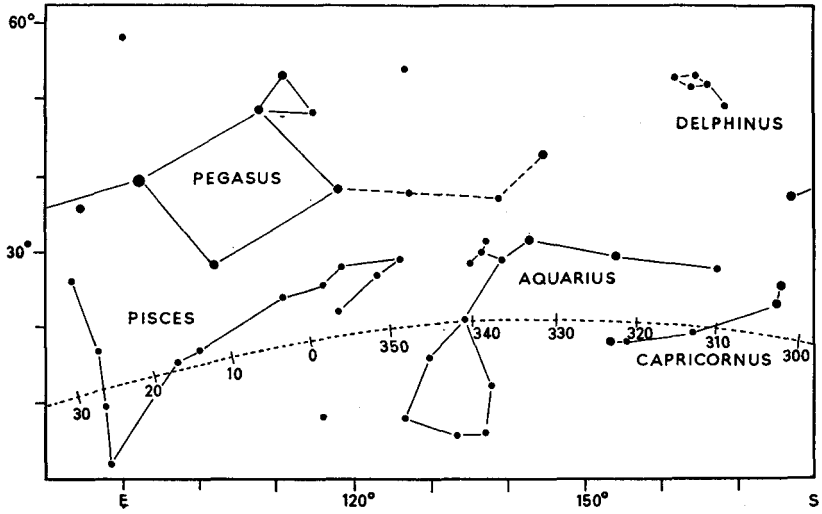
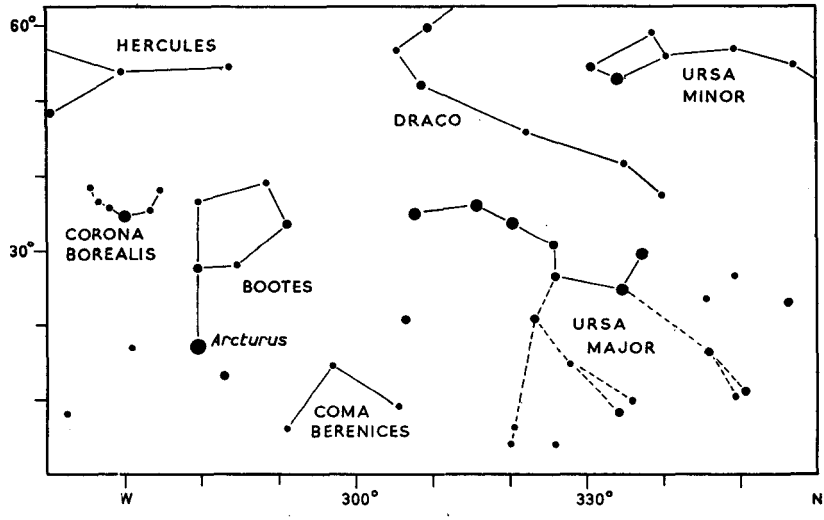
July 6 at 1h	July 21 at midnight
August 6 at 23h	August 21 at 22h
September 6 at 21h	September 21 at 20h
October 6 at 19h	October 21 at 18h
November 6 at 17h	November 21 at 16h





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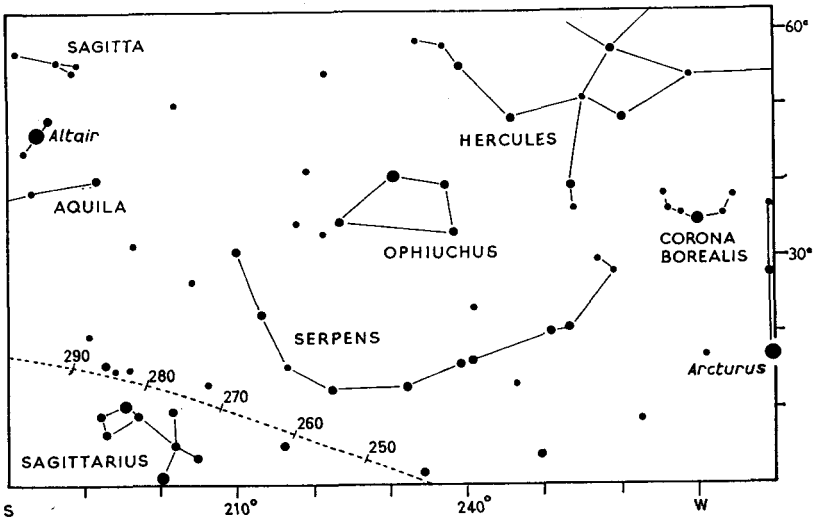
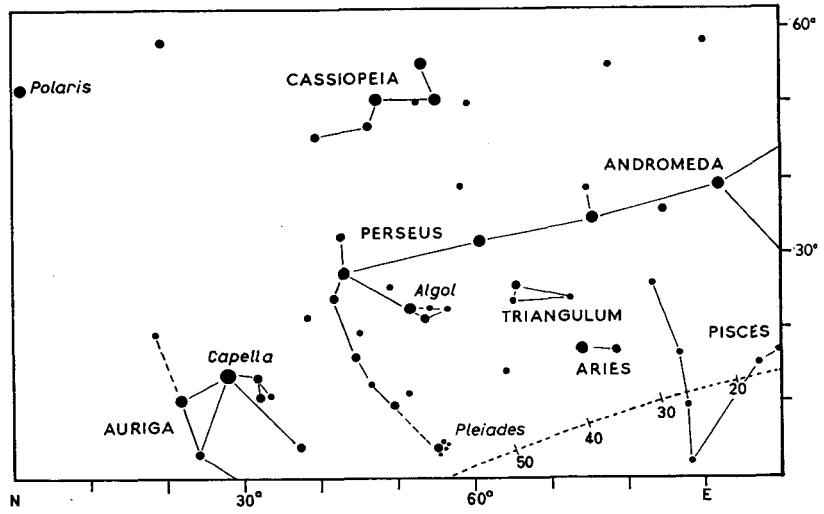
August 6 at 23h	August 21 at 22h
September 6 at 21h	September 21 at 20h
October 6 at 19h	October 21 at 18h
November 6 at 17h	November 21 at 16h

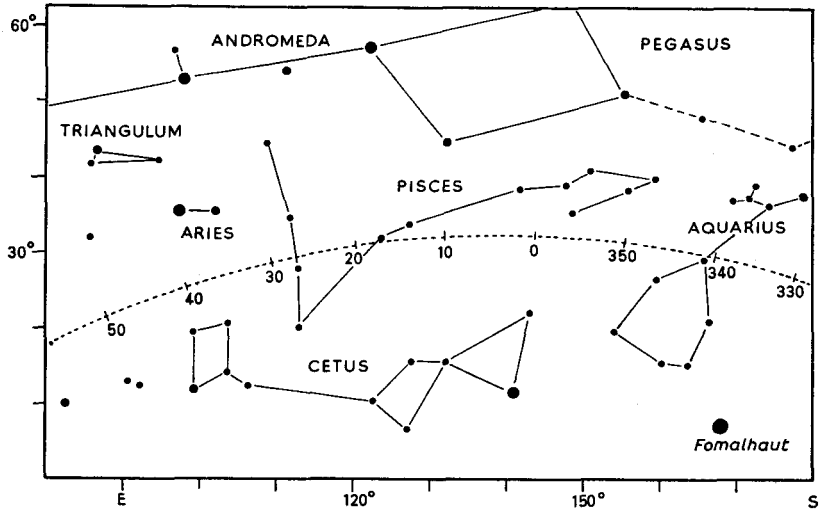
8R

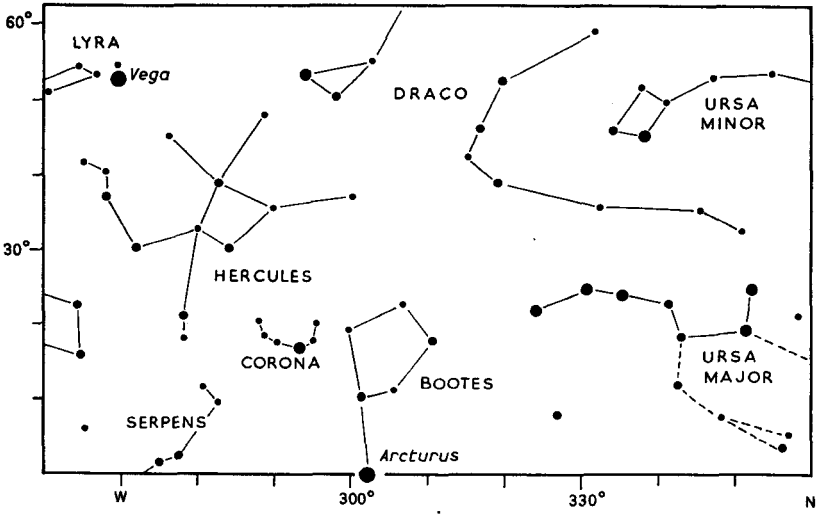




9L

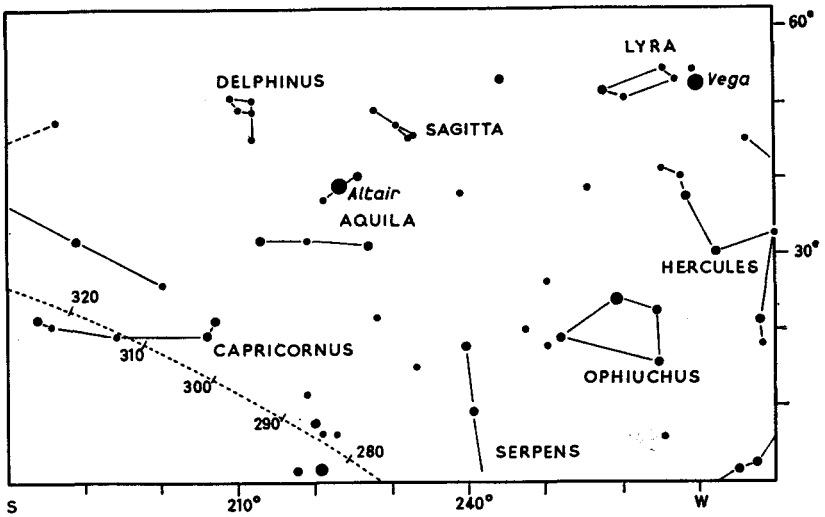
August 6 at 1h	August 21 at midnight
September 6 at 23h	September 21 at 22h
October 6 at 21h	October 21 at 20h
November 6 at 19h	November 21 at 18h
December 6 at 17h	December 21 at 16h

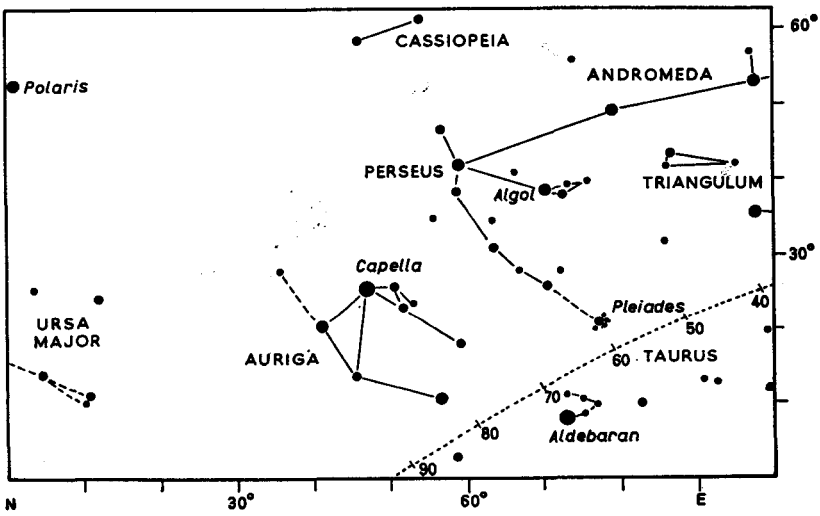




August 6 at 1h	August 21 at midnight
September 6 at 23h	September 21 at 22h
October 6 at 21h	October 21 at 20h
November 6 at 19h	November 21 at 18h
December 6 at 17h	December 21 at 16h

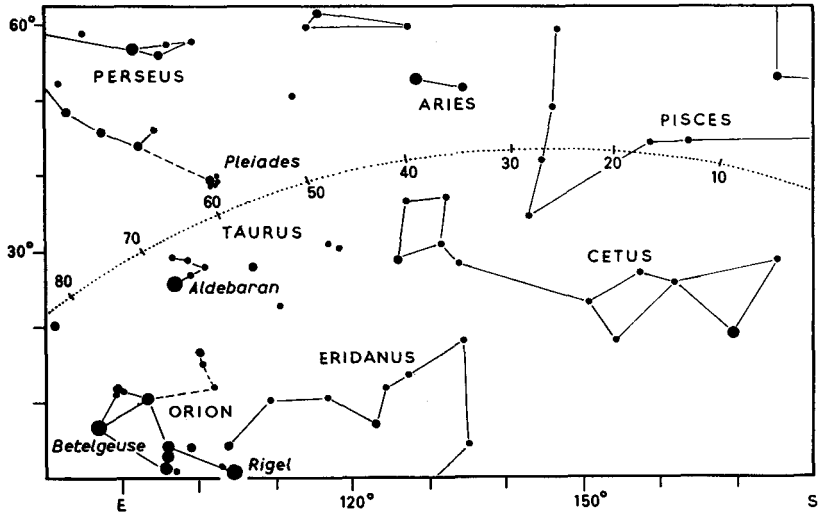
9R

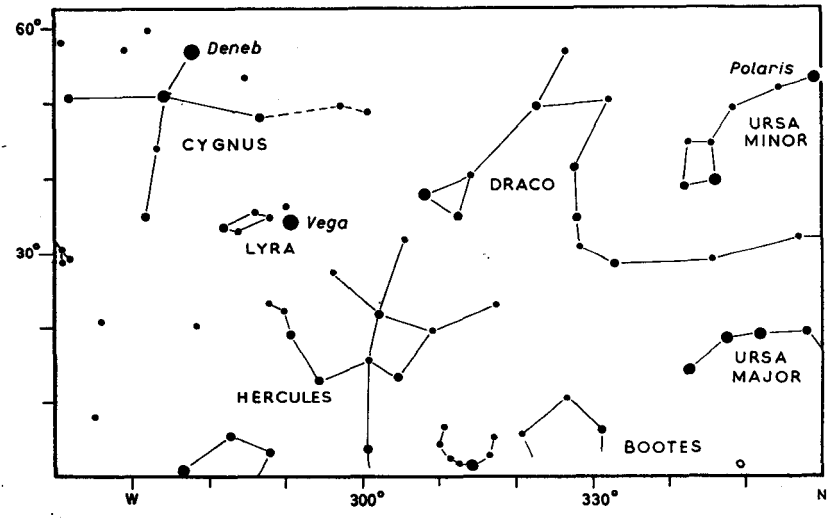




10L

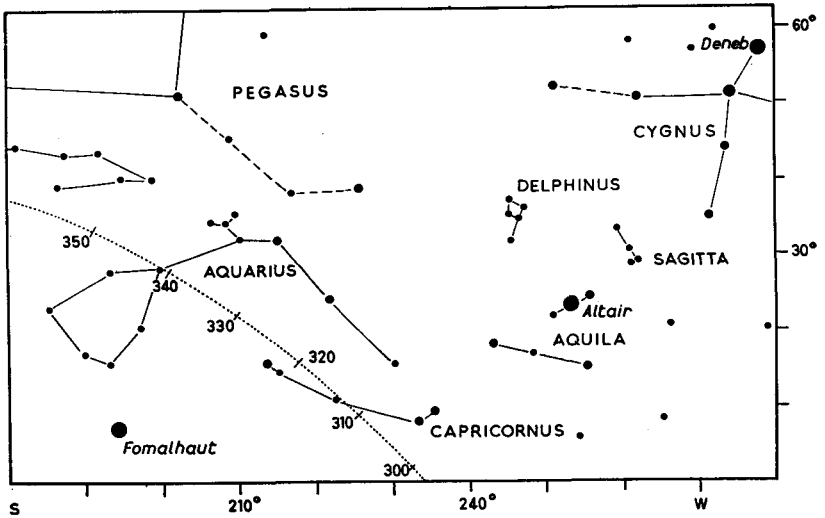
August 6 at 3h	August 21 at 2h
September 6 at 1h	September 21 at midnight
October 6 at 23h	October 21 at 22h
November 6 at 21h	November 21 at 20h
December 6 at 19h	December 21 at 18h

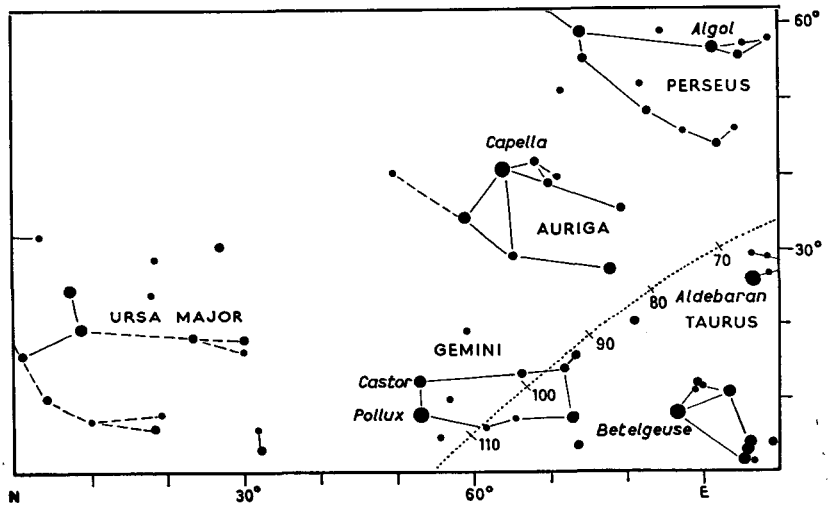




August 6 at	3h	August 21 at	2h
September 6 at	1h	September 21 at	midnight
October 6 at	23h	October 21 at	22h
November 6 at	21h	November 21 at	20h
December 6 at	19h	December 21 at	18h

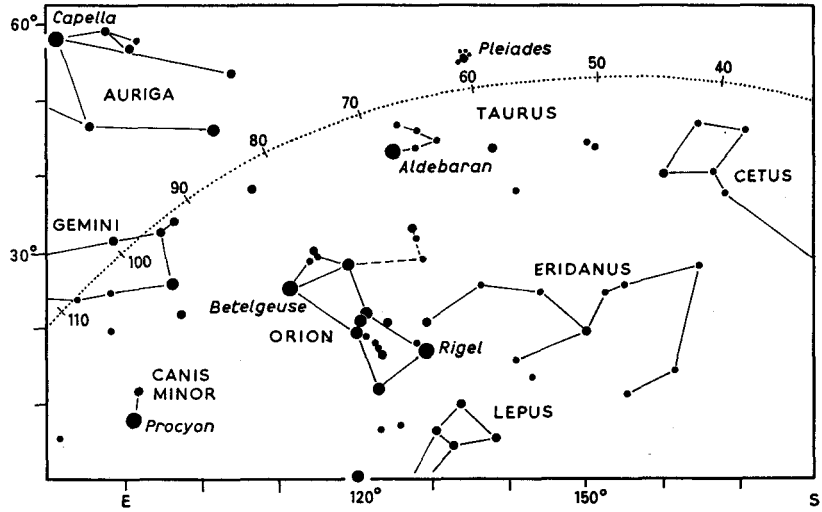
10R

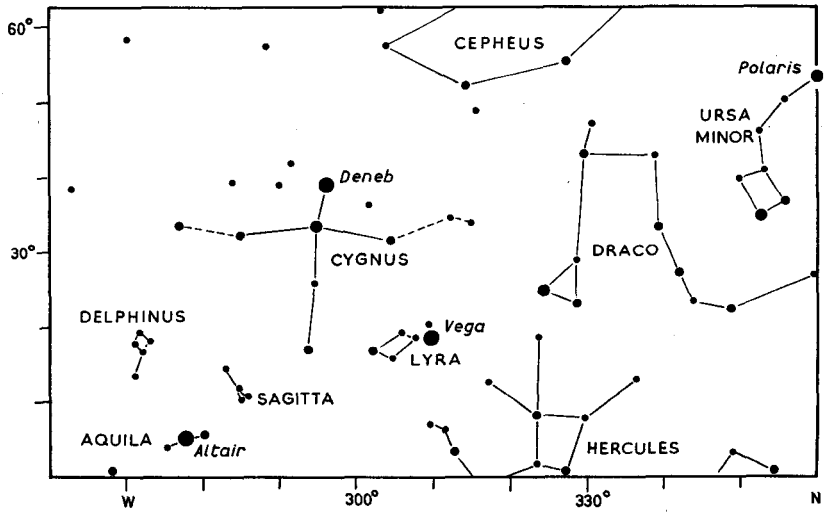




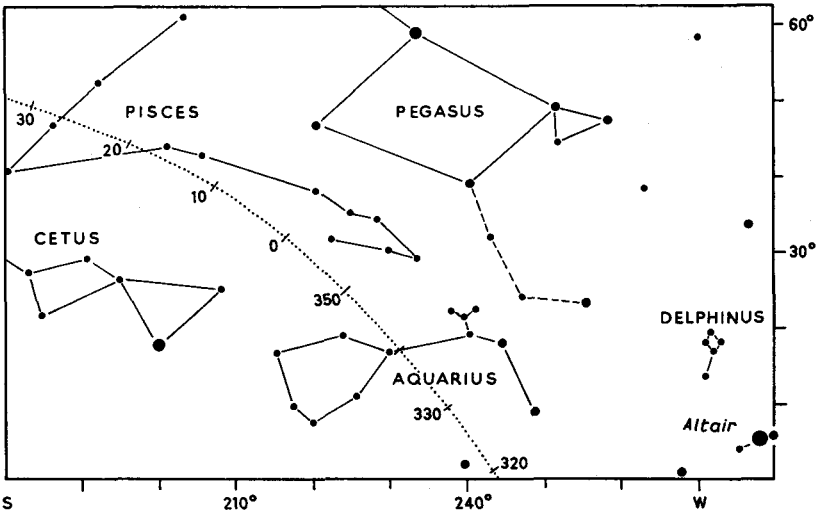
11L

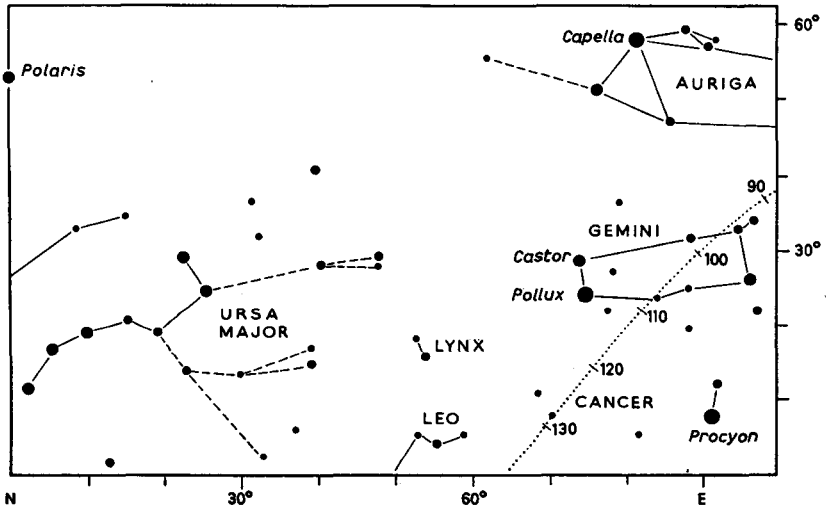
September 6 at 3h	September 21 at 2h
October 6 at 1h	October 21 at midnight
November 6 at 23h	November 21 at 22h
December 6 at 21h	December 21 at 20h
January 6 at 19h	January 21 at 18h





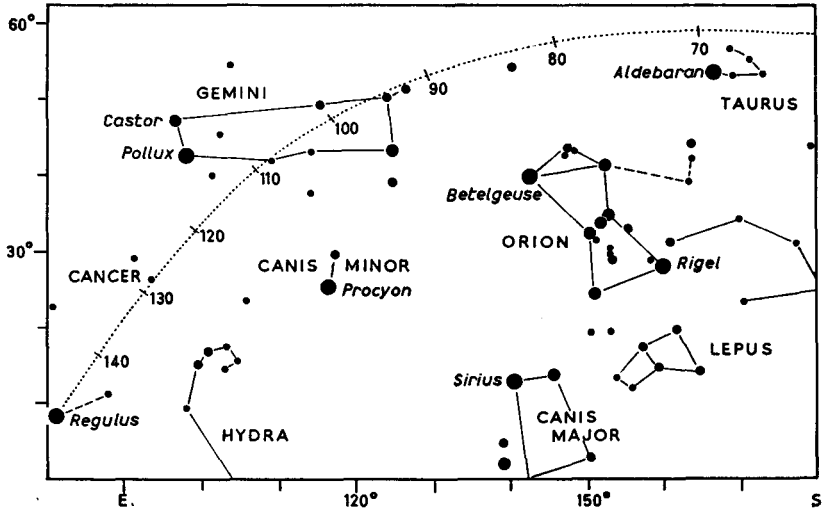
September 6 at 3h	September 21 at 2h	**11R**
October 6 at 1h	October 21 at midnight	
November 6 at 23h	November 21 at 22h	
December 6 at 21h	December 21 at 20h	
January 6 at 19h	January 21 at 18h	

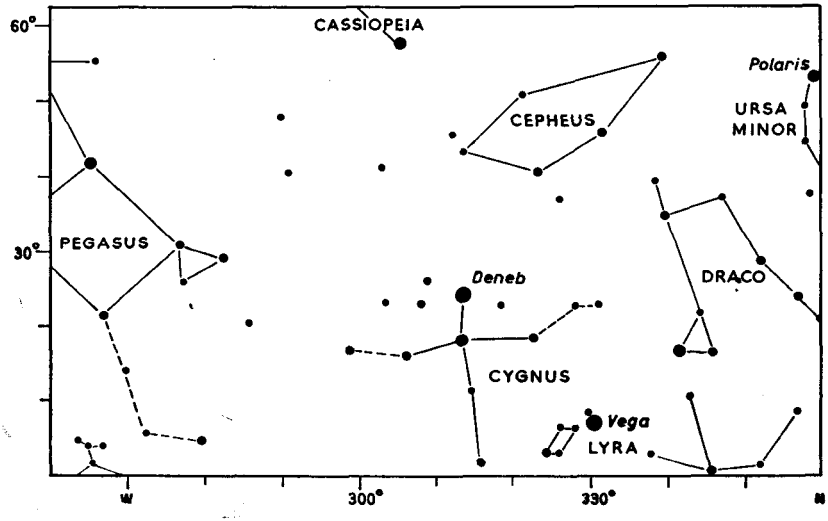




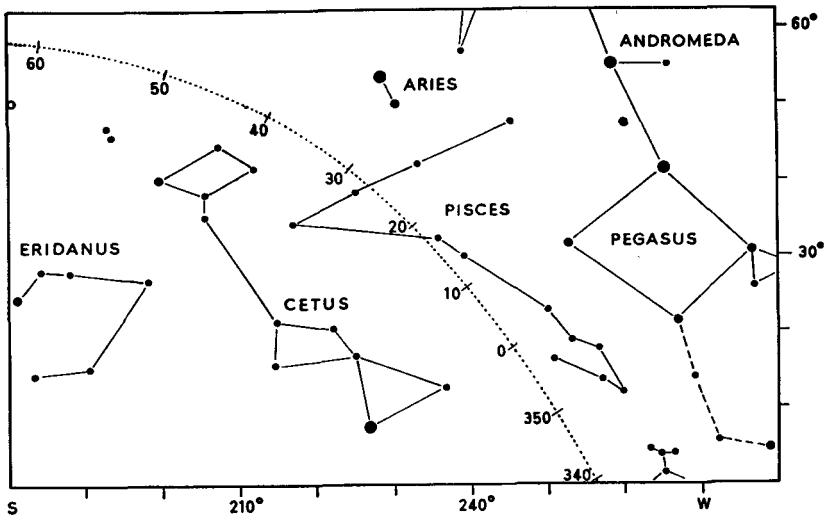
12L

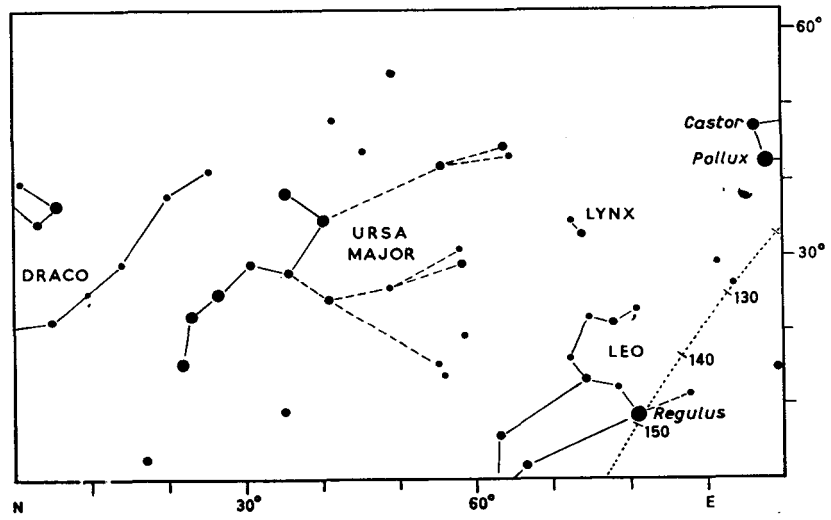
October 6 at 3h	October 21 at 2h
November 6 at 1h	November 21 at midnight
December 6 at 23h	December 21 at 22h
January 6 at 21h	January 21 at 20h
February 6 at 19h	February 21 at 18h

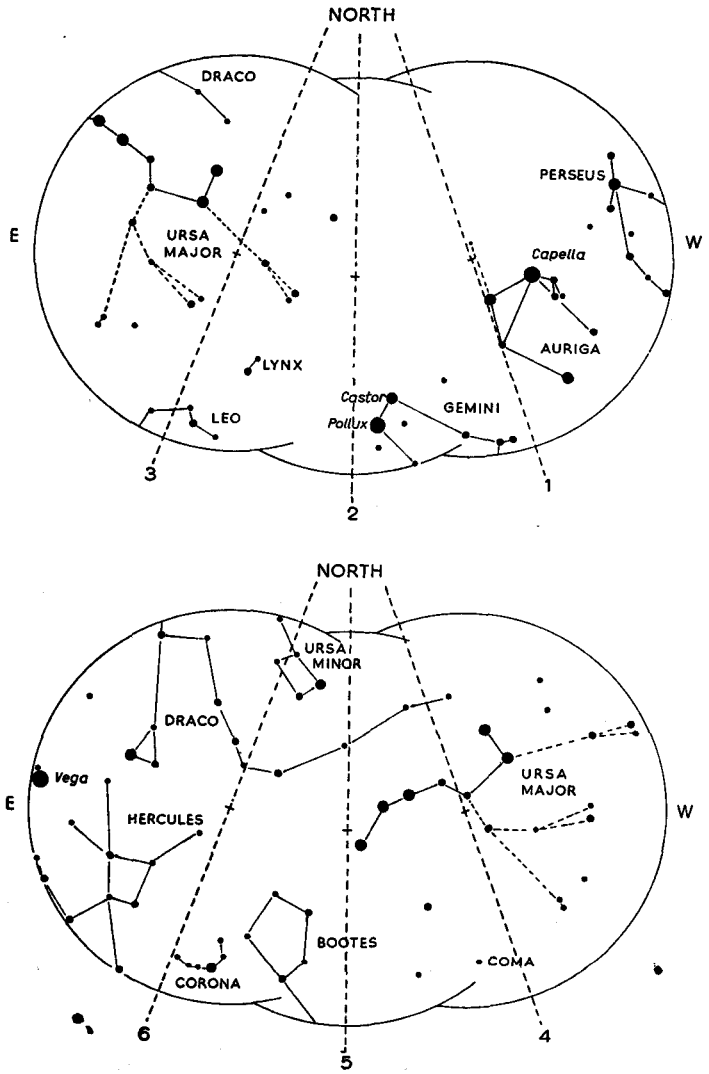




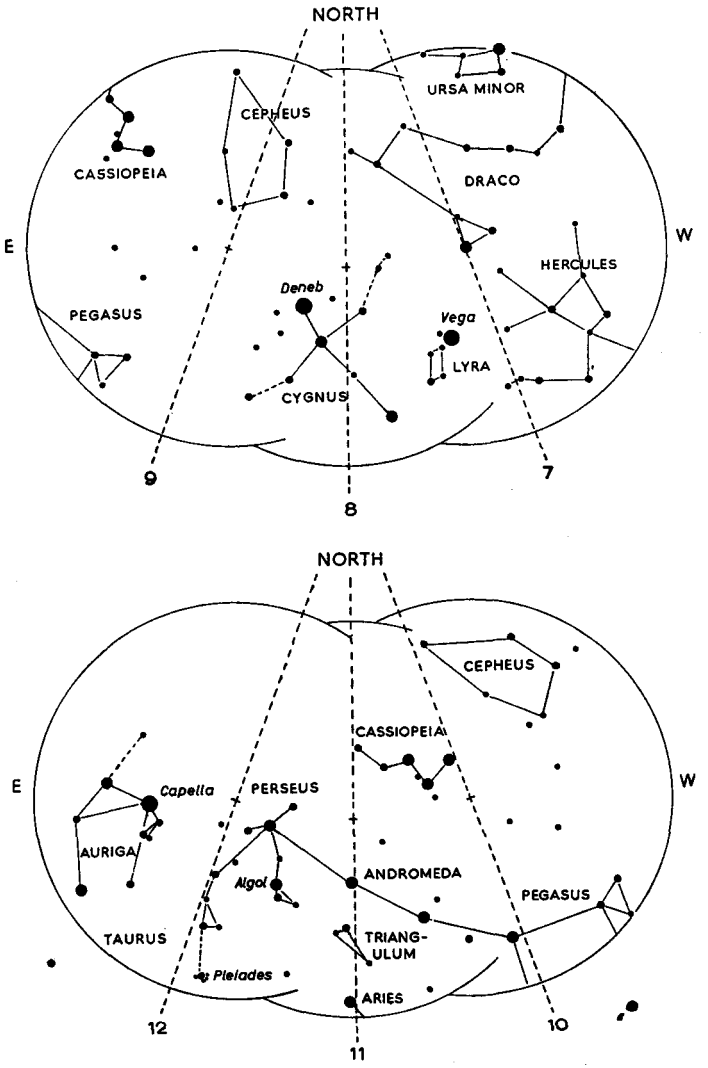
October 6 at 3h	October 21 at 2h	**12R**
November 6 at 1h	November 21 at midnight	
December 6 at 23h	December 21 at 22h	
January 6 at 21h	January 21 at 20h	
February 6 at 19h	February 21 at 18h	







Overhead stars



Overhead stars

The Planets in 1965

DATE		*Venus*	*Mars*	*Jupiter*	*Saturn*	*Uranus*	*Neptune*
January	6	262°	176°	46°	332°	165°	230°
	21	281°	179°	47°	334°	165°	230°
February	6	301°	179°	48°	336°	164°	230°
	21	320°	176°	49°	338°	164°	230°
March	6	336°	172°	51°	339°	163°	230°
	21	355°	166°	54°	341°	162°	230°
April	6	15°	161°	57°	343°	162°	230°
	21	33°	160°	60°	344°	161°	230°
May	6	52°	161°	63°	346°	161°	229°
	21	70°	164°	67°	347°	161°	229°
June	6	90°	170°	70°	348°	161°	228°
	21	108°	176°	74°	348°	161°	228°
July	6	127°	184°	77°	348°	162°	228°
	21	145°	192°	80°	348°	163°	228°
August	6	164°	201°	83°	347°	164°	228°
	21	182°	210°	86°	346°	164°	228°
September	6	201°	220°	88°	345°	165°	228°
	21	218°	230°	90°	344°	166°	228°
October	6	235°	241°	91°	343°	167°	229°
	21	252°	252°	91°	342°	168°	229°
November	6	270°	264°	91°	341°	169°	230°
	21	286°	275°	90°	341°	169°	231°
December	6	300°	287°	88°	342°	170°	231°
	21	310°	298°	86°	342°	170°	232°
Conjunction: Superior		Apr. 12	—	May 30	Feb. 26	Sept. 8	Nov. 12
Opposition:		—	Mar. 9	Dec. 18	Sept. 6	Mar. 3	May 9

Mercury moves so quickly among the stars that it is not possible to indicate its position on the star charts at a convenient interval. The monthly notes must be consulted for the best times at which this planet may be seen.

The positions of the other planets are given in the table on the opposite page. This gives the apparent longitudes on dates which correspond to those of the star charts, and the position of the planet may at once be found near the ecliptic at the given longitude.

Examples:

(1) *What is the bright planet seen in the east, above and to the left of Orion, at 1 a.m. (Summer Time) on September 20?*
The time is 0^h G.M.T. and from the table on page 2 the appropriate star chart is number 10. From this chart the longitude of the planet is seen to be about 90 degrees, and the table opposite indicates that the planet is Jupiter.

(2) *Where can Saturn be found on October 22?*
From the table opposite, it is clear that Saturn has passed opposition, and is therefore an evening star; the longitude is given as 342 degrees. Using charts, 8, 9, 10, as indicated on page 2 for October evenings, Saturn is found to be in the south at about 21^h, in the constellation Aquarius.

Phases of the Moon, 1965

New Moon				*First Quarter*				*Full Moon*				*Last Quarter*			
	d	h	m		d	h	m		d	h	m		d	h	m
Jan.	2	21	07	Jan.	10	20	59	Jan.	17	13	37	Jan.	24	11	07
Feb.	1	16	36	Feb.	9	08	53	Feb.	16	00	27	Feb.	23	05	39
Mar.	3	09	56	Mar.	10	17	52	Mar.	17	11	24	Mar.	25	01	37
Apr.	2	00	21	Apr.	9	00	40	Apr.	15	23	02	Apr.	23	21	07
May	1	11	56	May	8	06	20	May	15	11	52	May	23	14	40
May	30	21	13	June	6	12	11	June	14	01	59	June	22	05	36
June	29	04	52	July	5	19	36	July	13	17	01	July	21	17	53
July	28	11	45	Aug.	4	05	47	Aug.	12	08	22	Aug.	20	03	50
Aug.	26	18	50	Sept.	2	19	27	Sept.	10	23	32	Sept.	18	11	58
Sept.	25	03	18	Oct.	2	12	37	Oct.	10	14	14	Oct.	17	19	00
Oct.	24	14	11	Nov.	1	08	26	Nov.	9	04	15	Nov.	16	01	54
Nov.	23	04	10	Dec.	1	05	24	Dec.	8	17	21	Dec.	15	09	52
Dec.	22	21	03	Dec.	31	01	46								

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The Planets and the Ecliptic

The paths of the planets about the Sun all lie close to the plane of the ecliptic, which is marked for us in the sky by the apparent path of the Sun among the stars, and is shown on the star charts by a broken line. The Moon and planets will always be found close to this line, never departing from it by more than about 7 degrees. Thus the planets are most favourably placed for observation when the ecliptic is well displayed, and this means that it should be as high in the sky as possible. This avoids the difficulty of finding a clear horizon, and also overcomes the problem of atmospheric absorption, which greatly reduces the light of the stars. Thus a star at an altitude of 10 degrees suffers a loss of 60 per cent of its light, which corresponds to a whole magnitude; at an altitude of only 4 degrees, the loss may amount to two magnitudes.

The position of the ecliptic in the sky is therefore of great importance, and since it is tilted at about 23½ degrees to the equator, it is only at certain times of the day or year that it is displayed to the best advantage. It will be realized that the Sun (and therefore the ecliptic) is at its highest in the sky at noon in midsummer, and at its lowest at noon in midwinter. Allowing for the daily motion of the sky, these times lead to the fact that the ecliptic is highest at midnight in winter, at sunset in the spring, at noon in summer, and at sunrise in the autumn. Hence these are the best times to see the planets. Thus, if Venus is an evening star, in the western sky after sunset, it will be seen to best advantage if this occurs in the spring, when the ecliptic is high in the sky and slopes down steeply to the north-west. This means that the planet is not only higher in the sky, but will remain for a much longer period above the horizon. For similar reasons, a morning star will be seen at its best on autumn mornings before sunrise, when the ecliptic is high in the east. The outer planets, which can come to opposition and are then in the south at midnight, are best seen when opposition occurs in the winter months. Clearly the summer is the least favourable time to observe the planets, for the ecliptic is always low in the sky on summer nights.

Notes on the Planets in the monthly diagrams

The following general notes on observing the planets are followed by detailed month-by-month accounts of the behaviour of the planets, and of other interesting phenomena. These monthly notes include diagrams of the planetary orbits, and of the apparent movements of the planets at favourable times of the year. Additional notes on other astronomical phenomena will be found on the following pages.

The monthly diagrams of the orbits of the planets are intended to give a picture of the way in which the planets move about the Sun during the month. These diagrams are similar to those that were given many years ago in the old *English Mechanic*, and which were also adopted for some time in the *Journal* of the B.A.A. The motions of the planets are all anti-clockwise, and the movement during the month is indicated by the thickened line; the longitudes are measured from the Equinox, marked 0°. It is difficult to show all the orbits to scale, since the distance of Pluto from the Sun is about a hundred times that of Mercury. For this reason, only the orbits of the inner planets (Mercury to Mars) are shown to scale, those of the outer planets being merely suggested in the diagrams. A line drawn from the Earth to any other planet will give a rough idea of the apparent longitude of that body, but a more accurate value can be obtained from the table on page 30, and this will enable the position of the planet to be found on the monthly star-charts.

The inferior planets, Mercury and Venus, move in smaller orbits than that of the Earth, and so are always seen near the Sun. They are most obvious at the times of greatest angular distance from the Sun (greatest elongation), which may reach 28 degrees for Mercury, or 47 degrees for Venus. They are then seen as evening stars in the western sky after sunset (at eastern elongations) or as morning stars in the eastern sky before sunrise (at western elongations). The succession of phenomena, conjunctions and elongations, always follows the same order, but the intervals

between them are not equal. Thus if either planet is moving round the far side of its orbit its motion will be to the east, in the same direction in which the Sun appears to be moving. It therefore takes much longer for the planet to overtake the Sun – that is, to come to superior conjunction – than it does when moving round to inferior conjunction, between Sun and Earth. The intervals given in the following table are average values; they remain fairly constant in the case of Venus, which travels in an almost circular orbit. In the case of Mercury, however, conditions vary widely because of the great eccentricity and inclination of the planet's orbit.

			Mercury	*Venus*
Inferior conj.	to	Elongation West	22 days	72 days
Elongation West	to	Superior conj.	36 days	220 days
Superior conj.	to	Elongation East	36 days	220 days
Elongation East	to	Inferior conj.	22 days	72 days

The greatest brilliancy of Venus always occurs about a month *before* greatest western elongation (as a morning star), or a month *after* greatest eastern elongation (as an evening star). No such rule can be given for Mercury, because its distance from Sun and Earth can vary over a wide range.

Mercury is not likely to be seen unless a clear horizon is available; it is seldom seen as much as 10 degrees above the horizon in the twilight sky. In general it may be said that the most favourable times for seeing Mercury as an evening star will be in spring, some days before greatest eastern elongation; in autumn it may be seen as a morning star some days after greatest western elongation.

Venus is the brightest of the planets, and may be seen on occasions in broad daylight. Like Mercury, it is alternately a morning and an evening star, and will be highest in the sky when it is a morning star in autumn, or an evening star in spring. Venus is seen to best advantage when it comes to greatest eastern elongation in June; it is then well north of the Sun in the spring months and is a brilliant object in the sunset sky over a long period.

The superior planets, which travel in orbits larger than that of the Earth, differ from Mercury and Venus in that they can be seen opposite the Sun in the sky. The superior planets are morning stars after conjunction with the Sun, rising earlier each day until they

come to opposition. They will then be in the south at midnight, and visible all night. After opposition, they are evening stars, setting earlier each evening until they set in the west with the Sun at the next conjunction. The interval between conjunctions or between oppositions is greatest for Mars (over two years). At the time of opposition, the planet is nearest the Earth, and therefore at its brightest. This change in brightness is most noticeable with Mars, whose distance from the Earth can vary considerably; the other superior planets are at such great distances that there is very little change in brightness from one opposition to another. The effect of altitude is, however, of importance, for at a December opposition the planet will be among the stars of Taurus or Gemini, and can then be at an altitude of more than 60 degrees in southern England. At a summer opposition, when the planet is in Sagittarius, it may only rise to about 15 degrees above the southern horizon, and so make a less impressive appearance.

Mars, whose orbit is appreciably eccentric, comes nearest to the Earth at an opposition at the end of August; it may then be brighter even than Jupiter, but rather low in the sky in Aquarius. These favourable oppositions occur every fifteen or seventeen years (1924, 1941, 1956, 1973), but in this country the planet is probably better seen at an opposition in the autumn or winter, when it is higher in the sky. Oppositions of Mars occur at an average interval of 780 days, and during this time the planet makes a complete circuit of the sky.

Jupiter is always a bright planet, and comes to opposition a month later each year, having moved, roughly speaking, from one Zodiacal constellation to the next.

Saturn moves much more slowly than Jupiter, and may remain in the same constellation for several years. The brightness of Saturn depends on the aspect of its rings, as well as on the distance from Earth and Sun. The rings are now closing, but the planet is still a bright object.

Uranus, *Neptune* and *Pluto* are hardly likely to attract the attention of observers without adequate instruments, but some notes on their present positions in the sky will be found in the March and May notes.

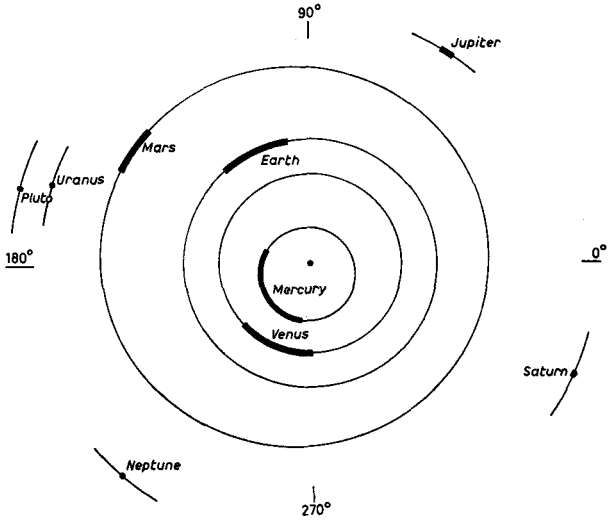
MONTHLY NOTES, 1965

January

New Moon: January 2 *Full Moon:* January 17

Earth is at perihelion (nearest to the Sun) on January 2, its distance from the Sun being then 91,400,000 miles.

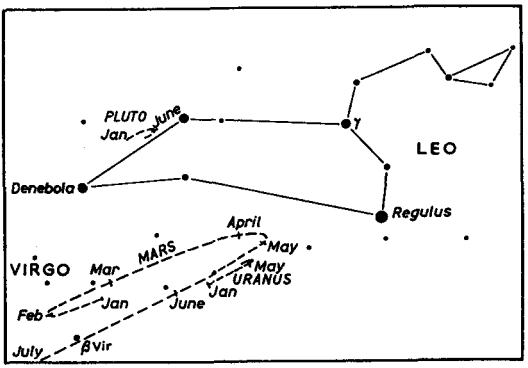
Mercury is a morning star, at greatest western elongation (23 degrees) on January 8. It is well north of the ecliptic at this time, and may possibly be glimpsed in the south-east at low altitude at dawn. It should not be confused with Venus, which is in the same part of the sky, but much brighter.



Planetary Orbits in January

Venus is a morning star in the first few weeks of the year—a brilliant object in the south-east at dawn. At the beginning of January it rises nearly two hours before the Sun, but this interval rapidly decreases as the planet moves in to conjunction.

Mars rises in the east in the late evening in the constellation Virgo. As will be seen from the star-chart below, the planet moves direct until January 29, when it reaches a stationary point north-east of the fourth-magnitude star Beta Virginis. The planet is now a very bright object, and as the distance from the Earth decreases, there is a corresponding increase in the brightness (102 million miles on January 1, 67 million on February 1) the magnitude changing from +0·5 to −0·2.



Mars, January–June

Jupiter is an evening star, and will be seen in the south in the evening sky. The planet was at opposition in 1964 November, and it is still the brightest object in the evening sky, apart from the Moon. (Magnitude −2·2 to −2·0.) On January 10 it reaches a stationary point in the constellation Aries, and then begins once more to move direct (see chart on page 54).

Saturn is also an evening star, setting about two hours after the Sun, in the constellation Aquarius. It is still a bright object (magnitude +1·1), but is now moving in to conjunction with the Sun.

The Quadrantids. The first meteor shower of the year has a strange-sounding name, not associated with any now-accepted constellation; it comes from the old group of Quadrans Muralis (the Mural

Quadrant), which has long since disappeared from the star maps. This is a shower with a very sharp maximum, but it should be well seen in 1965, since the Moon is virtually new and will not interfere on the night of maximum (January 3).

Forgotten Constellations. Quadrans is by no means the only rejected constellation, and in fact the list is quite extensive. From an historical point of view, it is interesting to look back at the various groups which have been proposed, but which have not survived.

Ptolemy, in his great work written in the second century A.D., enumerated forty-eight constellations; twelve Zodiacal, twenty-one in the northern hemisphere of the sky, and fifteen in the southern. Not all the northern sky was covered, and Ptolemy could naturally know nothing about that part of the sky which never rises above the horizon at his home in Alexandria. However, all his constellations are still accepted, though in many cases the boundaries have been modified. The list includes almost all the famous groups visible in Europe, such as Ursa Major, Cygnus, Andromeda and Orion. A few very small constellations also prove, surprisingly, to be 'Ptolemaic' – notably Equuleus, Sagitta, Delphinus and Crater.

The first additions to the list seem to have been made by Tycho Brahe, in the late sixteenth century, who proposed Coma Berenices and Antinous; the former has survived, the latter has not. Then Bayer, in his star maps of 1603, added twelve southern constellations such as Pavo, Grus, Hydrus, and Triangulum Australe, all of which lay in regions inaccessible to Ptolemy and which are still used. Oddly enough, the celebrated Southern Cross (Crux Australis) dates only from 1679, when it was included in some star maps by Royer. (The last-century astronomer W. T. Lynn maintained that Royer simply 'borrowed' Crux and four more southern groups which are now rejected; but in any case, the Southern Cross must be regarded as relatively modern.)

Halley, about the same time, suggested a group to be known as Robur Caroli (Charles' Oak), but it met with no favour. Neither did Flamsteed's Cor Caroli or Mons Mænalus (Charles' Heart and the Mountain Mænalus), though the name of *Cor Caroli* has been

given to the brightish star Alpha Canum Venaticorum in the little group of the Hunting Dogs, and Canes Venatici itself is regarded as a separate constellation.

Hevelius, in 1690, tacked on nine northern and two southern constellations, one of which was Canes Venatici. Of these, the only one to be rejected is Triangulum Minor (the Little Triangle). Then, in 1752, Lacaille added fourteen southern groups, most of them small and most of them near the celestial pole; all are still to be found, and include Fornax, Octans and Telescopium. Some of the names, however, have been shortened; Lacaille's Reticulus Rhomboidalis (the Rhomboidal Net) has become simply Reticulum.

These were the last accepted additions. Lemonnier, in 1776, proposed two more groups, Tarandus (the Reindeer) and Solitarus (the Solitaire) which have vanished; Poczobut, in 1777, added Taurus Poniatowskii (Poniatowski's Bull); and finally, Bode put forward nine new groups with barbarous names such as Sceptrum Brandenburgicum (the Sceptre of Brandenburg) and Globus Ærostaticus (the Balloon). All the groups were too small to merit separate names, and were deservedly abandoned.

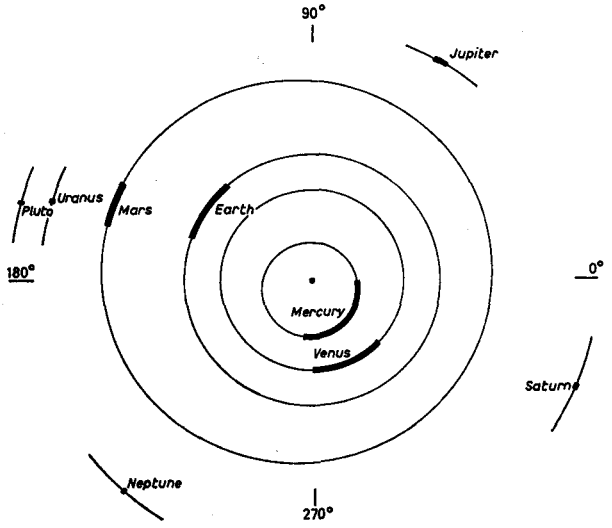
It cannot be said that the present division of the stars into constellations is ideal, but it is unlikely that any further modifications will be made now.

February

New Moon: February 1 *Full Moon:* February 16

Mercury is at superior conjunction on February 24, and will not be visible during the month.

Venus is still a morning star, but is well south of the Sun, and rises only a short time before sunrise. It is therefore unlikely to be seen for the next few months.



Planetary Orbits in February

Mars is now approaching opposition, and rises in the east in mid-evening. The planet is in the constellation Virgo, and it continues its rapid increase in brightness (magnitude −0·2 to −0·9). This is not a very favourable opposition, since Mars is at aphelion on February 6 (155 million miles from the Sun, 73 million from the Earth). The planet will be seen near the Moon (one day past the Full) on February 17.

Jupiter is an evening star, setting in the west at midnight at the end of February. Although fading a little (magnitude −2·0 to −1·9), the planet is still a brilliant object, and forms a fine spectacle with the bright stars of Orion on its left, and the cluster of the Pleiades above it.

Saturn is at conjunction with the Sun on February 26, and it rapidly disappears from view as the evenings begin to draw out.

The Shortest Month. The present calendar cannot be regarded as ideal; but it would be hard to devise a perfect calendar, since the true length of the Earth's sidereal period is about 365¼ days instead of exactly 365. However, the shortness of February is due to reasons which are not, strictly speaking, astronomical.

The 365-day calendar was adopted at an early stage, and was used by the Egyptians (replacing a still earlier 'year' of 360 days). The first Roman calendars were imperfect, and in 44 B.C. Julius Cæsar decided to undertake a revision, carried out at his command by the astronomer Sosigenes. It was Sosigenes who adopted a 365-day year, but this was a quarter of a day too short, so that an extra day would have to be added every 4 years – leap year, in fact. The number of months remained at 12, but since 12 will not divide exactly into 365 the months had to be unequal. On the Julian system, the first month became January instead of March, as previously; January, March, May, July, September and November had 31 days each and the rest 30, apart from February, which had 29. The leap-year day was therefore tacked on to February. Incidentally, July was a new name, in honour of Julius Cæsar; previously the month had been called Quintilis.

When Augustus attained supreme power, he clearly had to have a month of his own, and the old Sextilis was renamed August. Unfortunately August had only 30 days, as against the 31 days for Cæsar's month. This would not do, and so a day was taken away from February and added to August, with suitable readjustments elsewhere.

The Julian calendar was fairly accurate, but even when allowance was made for leap-year the length was now 11 minutes 14

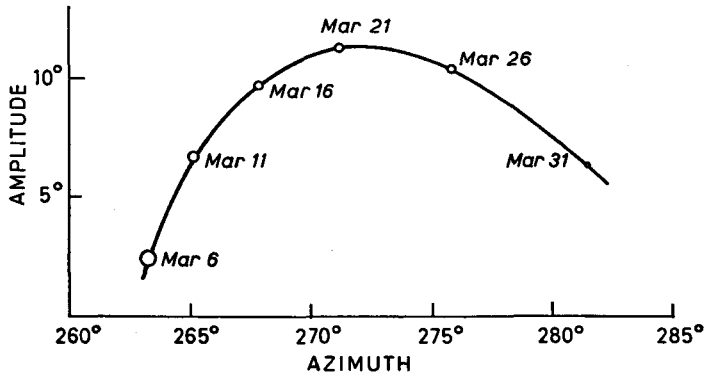
seconds too great. This adds up to a full day in 128 years. A new adjustment was made by Pope Gregory XIII, on the advice of the astronomer Clavius. Until then, every year which could be divided by 4 was a leap year, but Gregory ordered that the century years (1800, 1900, etc.) were to be regarded as leap years only if exactly divisible by 400. The error was thereby reduced to one day in 3,000 years, which is negligible. The Gregorian calendar was adopted in England in 1752, the days between September 2 and 14 being dropped from the calendar altogether.

From time to time there have been suggestions for a more accurate and convenient World Calendar, but no alterations have been officially supported as yet, and certainly the Gregorian calendar is quite good enough for most purposes.

March

New Moon: March 3 *Full Moon:* March 17
Equinox: March 20

Mercury is at greatest elongation east on March 21 (elongation 19 degrees), and this affords an excellent opportunity to see this planet as an evening star in the western sky just after sunset. The diagram shows the changes in altitude and azimuth (true bearing from the north through east, south and west) of Mercury on successive evenings at a time when the Sun is 6 degrees below the horizon; this will be about 30 minutes after sunset at this season.



Mercury, March

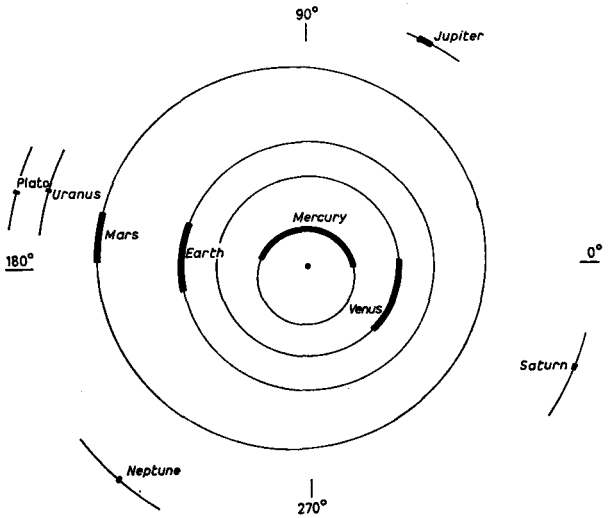
The sizes of the circles give an approximate indication of the expected brightness of the planet; it will be noticed that Mercury is much brighter before the date of greatest elongation.

Venus is theoretically a morning star, but it is now too close to the Sun to be seen in the dawn sky.

Mars is at opposition on March 9, and is then at its brightest (magnitude −1·0) and is visible all night. The actual closest approach to the Earth occurs three days later, on March 12 (distance 62 million miles), and after this date there is a rapid decrease in

the brightness of the planet. The north pole of Mars is directed towards the Earth and the Sun – it is late spring in the Martian northern hemisphere, and summer begins at the end of March. Mars will again be seen near the Moon (nearly at the Full) on March 16.

Jupiter is an evening star, setting in the west at midnight at the beginning of the month. It moves from Aries into Taurus at the end of March, when it will be about half a magnitude fainter than it was at opposition.



Planetary Orbits in March

Saturn is a morning star, but rises only a short while before the Sun, and is unlikely to be seen.

Uranus is at opposition on March 3, when it may be found in the constellation Leo (see chart on page 37). The magnitude of the planet at this time is +5·7, and it should just be possible to see it with the naked eye; in a small telescope it appears as a greenish disk. The distance of Uranus at this opposition is about 1,609

million miles from the Earth. The planet will probably be easier to identify at the times of its conjunctions with Mars (see April and May notes).

Pluto is at opposition on March 5, and is also in Leo, but well north of the ecliptic. The position of Pluto is shown, as a matter of interest, on the chart on page 37, but the planet is too faint to be seen with small instruments.

Problems of Mercury. Mercury, the innermost planet, is never a very conspicuous object with the naked eye, but when well placed – as at the end of this month and the beginning of April – it should be seen easily enough, provided that the sky near the horizon is perfectly clear. Sweeping with binoculars will often help, but if the Sun is still above the horizon this should not be attempted; there is always a chance that the Sun will come into the field of view, with disastrous results to the observer's eyesight.

Moderate telescopes will show the phases of Mercury, but almost nothing else. With a 6-inch reflector it may be possible to catch sight of the most prominent of the dark markings on the disk, but even this is somewhat dubious. It must be said, too, that maps of Mercury are probably of low accuracy; Antoniadi's chart, drawn with the aid of the 33-inch refractor at Meudon, and published more than 30 years ago, remains the best, though it is certainly capable of great improvement.

Neither are we at all sure of the nature of Mercury's surface. High mountains may or may not exist; it is also possible that there are lunar-type craters, though this is nothing more than speculation.

Since Mercury is not a great deal larger than the Moon (its diameter is only about 3,000 miles), its escape velocity is relatively low, and only a tenuous atmosphere is to be expected. Recently, the Russian astronomer N. Kozirev has supported the idea of an extremely thin, semi-permanent atmosphere, and traces of an atmosphere were reported 10 years ago by A. Dollfus in France, but this remains to be proved.

Mercury has a captured rotation; that is to say, it keeps the

same face turned permanently toward the Sun. This means that part of its surface is in permanent sunlight, while another part is in permanent darkness. However, the planet's orbit is appreciably eccentric, and there must be a 'twilight zone' over which the Sun would appear to rise and set. The breadth and position of this zone remains uncertain.

In every way Mercury is a hostile planet. It is entirely unsuitable for life on the terrestrial pattern, and manned landings there will probably be hazardous even when space-travel has become commonplace.

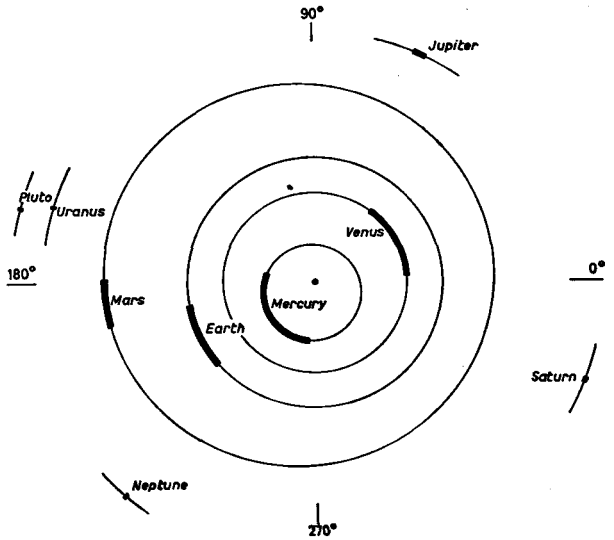
April

New Moon: April 2 *Full Moon:* April 15

Mercury is at inferior conjunction on April 8 and is therefore too close to the Sun to be seen during the month.

Venus is at superior conjunction on April 12, and after this date it becomes an evening star. However, it moves out from the Sun very slowly, and is not likely to be seen for some weeks.

Mars is an evening star to be seen in the south in mid-evening under the well-known figure of Leo. The planet has now passed opposition, and continues to fade rapidly (magnitudes −0·7 to 0·0); it reaches a stationary point on April 21, after which date its motion becomes direct. Mars will be 3 degrees north of the planet Uranus on April 3.



Planetary Orbits in April

Jupiter may still be seen as an evening star, setting north of west in mid-evening. It will be seen near the crescent Moon on the night of April 5 and will be south of the Pleiades in the middle of the month.

Saturn slowly emerges as a morning star, and by the end of the month rises in the east about an hour before sunrise. It will be found as a bright object (magnitude +1·3) to the right of the Great Square of Pegasus, and in a line with the stars Alpha and Beta Pegasi (see chart on page 59), which form the right-hand side of the Square.

Conjunction of Mars and Uranus. Uranus is just visible with the naked eye on a clear night, but looks exactly like a faint star. Small telescopes will, however, show that it is unstellar in appearance, since it shows a definite disk.

On April 3 Mars and Uranus will be close together in the sky, Mars lying a mere 3 degrees to the north; the days to either side of April 3 will therefore be very suitable for locating Uranus. Needless to say, this conjunction is a mere line-of-sight effect, and Uranus is a great deal farther away from Mars than we are!

Star Magnitudes. During April the magnitude of Mars ranges from −0·7 to 0·0. Since the apparent disk of a planet is small as seen with the naked eye, it approximates to a stellar point, and its magnitude may be given on the stellar scale.

Conventionally, stars visible to the naked eye are divided into six grades, magnitude 1 being the brightest and 6 the faintest. However, further refinements are needed for accurate work, and modern photoelectric methods are able to measure down to hundredths of a magnitude.

Only two stars (*Sirius* in Canis Major, and *Canopus* in the far southern constellation of Argo Navis) are much brighter than zero magnitude; *Sirius* is measured at −1·43, *Canopus* at −0·73. Older measures state that all other stars are below zero, but it has now been found that there are two more exceptions. Alpha Centauri, too far south to be visible in England, is −0·27, and *Arcturus*, the glorious K-type orange star in Boötes (the Herdsman) is −0·06. Next in order come *Vega*, *Rigel* and *Capella*, all of which are very slightly below zero.

In point of fact, Alpha Centauri is a binary whose components are not very unequal. The separate stars are both below zero

magnitude, and only when seen together as one object, with the naked eye, do they give the impression of a star which exceeds magnitude 0·0. Strictly speaking, then, the three apparently brightest separate stars in the sky are *Sirius*, *Canopus* and *Arcturus*.

Of the planets, Venus and Jupiter far exceed zero; so does Mars when at its closest – Mars can, in fact, become brighter than any other object in the sky apart from the Sun, the Moon and Venus. This year, unfortunately, the opposition of Mars is an aphelic one, so that the brightness does not rise to anything like this level.

Saturn and Mercury may both exceed zero magnitude, but so far as Mercury is concerned the precise magnitude is not obvious in view of the fact that the planet is never seen against a dark background. Uranus ranks as about magnitude 5·7, and Neptune, at 7·7, is well below naked-eye visibility. Pluto is fainter still, and to see it at all requires telescopes of some power.

Now and then a nova may flash out and exceed zero magnitude, the last two examples being Nova Persei 1901 and Nova Aquilæ 1918. The most brilliant 'new star' of which we have an accurate record was Tycho's Star of 1572, which was, of course, a supernova, and which became equal to Venus; it was visible in broad daylight. Its only subsequent rival has been Kepler's Star of 1604, which also seems to have been a supernova. However, it may well be that the supernova observed by Chinese astronomers in 1054 was at least the equal of these; it may even have been brighter. It has left the patch of gas which we now know as the Crab Nebula, and which is a powerful emitter of radio waves.

Venus at superior conjunction. When Venus is on the far side of the Sun, and at full phase, it is clearly very difficult to see. Observers with adequate telescopes, equipped with circles, may, however, follow it almost through superior conjunction. When attempting this sort of observation, great care must be taken, since Venus is close to the Sun in the sky and there is always the chance of finding the Sun by mistake. Inexperienced observers are strongly advised not to try it.

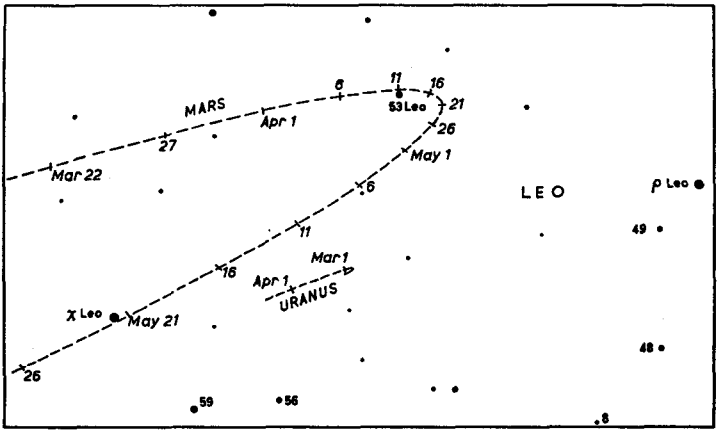
May

New Moon: May 1 and May 30 *Full Moon:* May 15

Mercury is at its greatest western elongation on May 6 (27 degrees), but is then in southern latitudes, and will not be at a sufficient altitude at dawn to be visible.

Venus is an evening star, still too close to the Sun to be easily observed. By the end of May it will be 13 degrees east of the Sun and it will be interesting to watch for the first glimpse of the planet, in the south-west at sunset.

Mars is an evening star, visible in the south-west after sunset, moving direct in Leo. The chart below shows the path of the planet at this time, together with stars down to the eighth magnitude. The three brightest stars in this field (Chi, Rho, and 53



Mars and Uranus

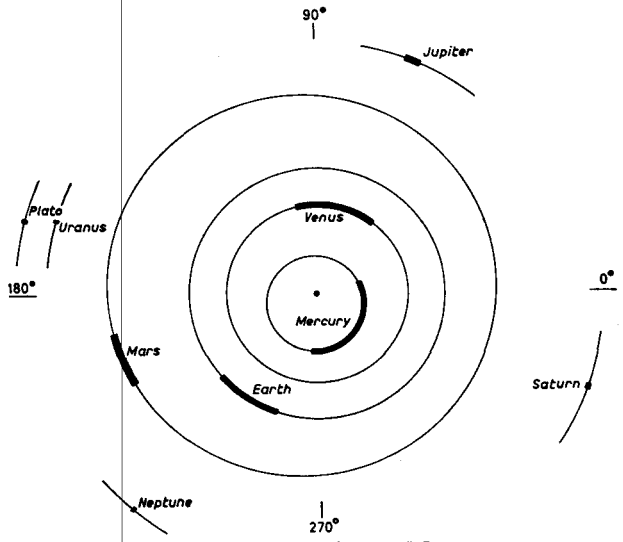
Leonis) are marked on Norton's *Star Atlas*. It will be seen that Mars again passes north of Uranus on May 6; this is the third such conjunction, the others having occurred on 1964 December 5 and 1965 April 3, but on this occasion Mars is only a degree north

of Uranus. Magnitudes, Mars 0·0, Uranus +5·7; for comparison, the magnitude of 53 Leonis is +5·3.

Jupiter is an evening star at the beginning of the month, its position being between the Hyades and Pleiades. It sets only about an hour after the Sun, and moves rapidly in to conjunction on May 30.

Saturn is a morning star, rising in the east in the early morning hours in the constellation Aquarius. Its magnitude is still +1·3.

Neptune is at opposition on May 9, and is then some degrees east of the third-magnitude star Alpha Libræ (*Zuben el Genubi*) as shown on the chart on page 69. Neptune is much fainter than any of the stars shown on this diagram, but may be seen in a small



Planetary Orbits in May

telescope as a greenish disk of magnitude +7·7. At opposition, the distance of Neptune from the Earth is about 2,726 million miles. A feature of the appearance of Neptune this year is the repeated close conjunctions of the Moon with this planet each month, some of these resulting in occultations of Neptune.

A total eclipse of the Sun on May 30 will be visible only in New Zealand and the Pacific Ocean (see also page 80).

Uranus. Uranus, discovered by Sir William Herschel in 1781, is a giant planet; its diameter is 29,300 miles, so that it is slightly larger than Neptune, even though somewhat less massive. In a small or moderate telescope it shows a distinctly greenish disk. Markings may be seen with larger apertures, but are not at all prominent.

The curious axial tilt of Uranus (98 degrees) means that we see it from unfamiliar angles. Twenty years ago the pole lay in the middle of the disk as viewed from Earth; by now the equator is presented. Observers with powerful telescopes may be able to record a faint feature across the equatorial zone, probably in the nature of a cloud belt. Bright spots have been reported from time to time, but are very hard to see.

The satellites are comparatively faint. Four (Ariel, Umbriel, Titania and Oberon) have been known for more than a century; the fifth (Miranda) is beyond the reach of any telescope available to amateurs, and is excessively elusive even with the world's largest instruments. Most textbooks say that Titania is the brightest of the better-known satellites, followed, in order, by Oberon, Ariel and Umbriel. There is no doubt that Umbriel is the faintest, but recent work by W. H. Steavenson indicates that Ariel is actually a little brighter than either Titania or Oberon, though it is closer to Uranus and therefore less easy to see.

It would be interesting to find the minimum aperture needed to see Titania and Oberon, the two most conspicuous satellites of Uranus, and observers with reflectors of 12 inches aperture or over may care to look out for them.

The 'Solitary One'. During May evenings much of the southern aspect is occupied by the huge, sprawling constellation of Hydra (the Watersnake). For all its area, Hydra has only one bright star. This is the second-magnitude *Alphard*, known popularly as 'the Solitary One' because of its isolated position. It is not hard to find; *Castor* and *Pollux* act as direction-indicators to it, and it also lies in line with the end star of the Great Bear (*Alkaid*) and *Regulus*

in Leo. It has a K-type spectrum, and is a fine sight in binoculars or a low-power telescope. Farther east, and lower down, look for the fairly bright quadrangle of stars which makes up the constellation of Corvus, the Crow sitting on the Watersnake's back. East again, and still lower, it may just be possible to make out a few of the stars of Centaurus (the Centaur). Centaurus is a brilliant constellation, but unfortunately it is so far south that almost all of it remains below the horizon in England.

June

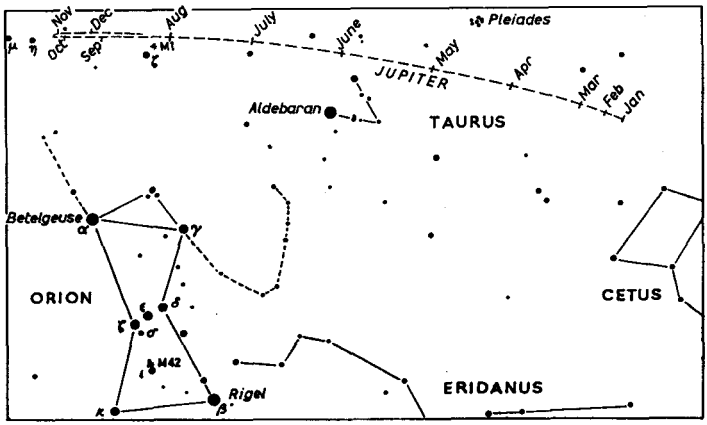
Full Moon: June 14 *New Moon:* June 29
Solstice: June 21

Mercury is at superior conjunction on June 11 and will not be visible during the month.

Venus now begins to appear as a bright evening star (magnitude −3·4), and it sets north of west about 1½ hours after the Sun. It reaches its highest northern declination in early June, and then begins to move south again.

Mars is still an evening star, setting in the west at midnight in early June. It is now moving more rapidly, and passes into Virgo in the middle of June. It continues to fade throughout the month (magnitudes +0·5 to +0·9).

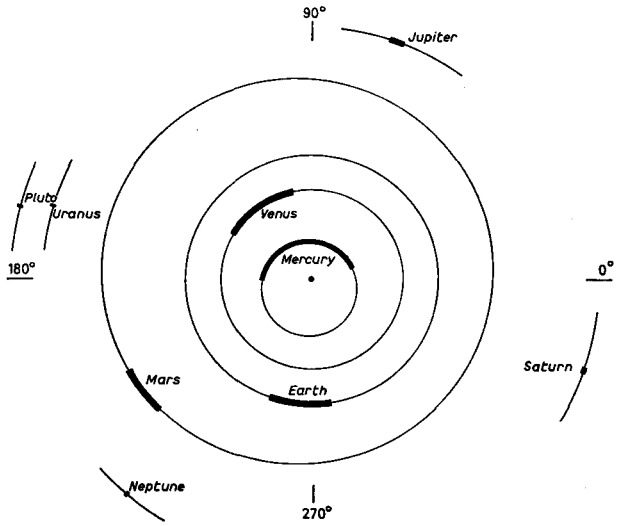
Jupiter now emerges as a morning star after conjunction with the Sun, and at the end of the month it rises 1½ hours before sunrise. It is a bright object (magnitude −1·5) in Taurus, north of the first-magnitude star *Aldebaran* (see chart below).



Jupiter, 1965

Saturn rises at midnight in mid-June, and may be seen in the early hours as a bright object on the borders of Pisces and Aquarius, below and to the right of the Great Square of Pegasus. It grows a little brighter (magnitude +1·2 at the end of June) and is the brightest object in this part of the sky. Saturn reaches a stationary point on June 29 and then begins its retrograde motion.

A partial eclipse of the Moon of small magnitude takes place on June 14 (see page 80).



Planetary Orbits in June

The eclipse of the Moon. In view of the fact that so little of the Moon's face is eclipsed on June 14, the phenomenon will be of only passing interest and little real importance even though it will still be worth watching.

Until recently, professional astronomers took little notice of lunar eclipses – though every effort was made to observe total eclipses of the Sun. However, the situation has altered in recent years. Immediately the supply of direct sunlight is cut off from

the Moon the temperature of the surface drops sharply, and the amount of decrease provides valuable information about the nature of the surface material. Luminescence phenomena may also be studied.

So far as amateur observers are concerned, the main interest of a lunar eclipse centres upon the possible effects upon certain special features. One of these is Linné, the small object on the Mare Serenitatis which is suspected of having altered radically in form between 1843 and 1866 – changing from a deep, well-marked crater into the present inconspicuous feature surrounded by a white nimbus. The whole question of Linné has been examined anew in recent years, and most authorities consider that no real change there took place, though the suspicion lingers on.

Between fifty and sixty years ago W. H. Pickering, S. A. Saunder and others claimed that during a lunar eclipse the white nimbus of Linné increased perceptibly in size. Pickering regarded this as evidence of the deposit of hoar-frost or something of the kind. Ideas of this sort have long since been rejected, but there have been later reports of an increase of Linné during an eclipse, and the feature is well worth studying at such times – though unfortunately the shadow during the eclipse of June 14 will not extend as far as Linné. It is also worth keeping a close watch upon the large dark-floored craters, such as Grimaldi and Plato, to see whether the sudden cold produces any changes. It is a pity that the shadow this month will not reach the most interesting areas in this respect.

The Scorpion. One of the most brilliant constellations in the sky is Scorpius, the Scorpion. It is one of Ptolemy's original 48 groups, and lies in the Zodiac. During June nights it can be conspicuous low over the southern horizon.

The leading star is *Antares* ('the Rival of Mars'), which is immediately recognizable, partly because of its strong red colour and partly because, like *Altair* in Aquila, it has a fainter star to either side of it – in this case Tau and Sigma Scorpionis. It is of the first magnitude, though it is very slightly variable. Together with its

faint green companion, it makes a fine sight in a moderate aperture. The greenish hue of the companion is, of course, accentuated by the contrast with the red primary.

Scorpius is rich in bright stars and interesting objects. Unfortunately it is always low as seen from England, and even lower from Scotland; the 'sting' made up of several bright stars, never rises from any part of Britain. For this reason European observers cannot appreciate how brilliant Scorpius really is. From places farther south in latitude the constellation is seen in its full glory. Meanwhile, the whole area is well worth sweeping with a low power.

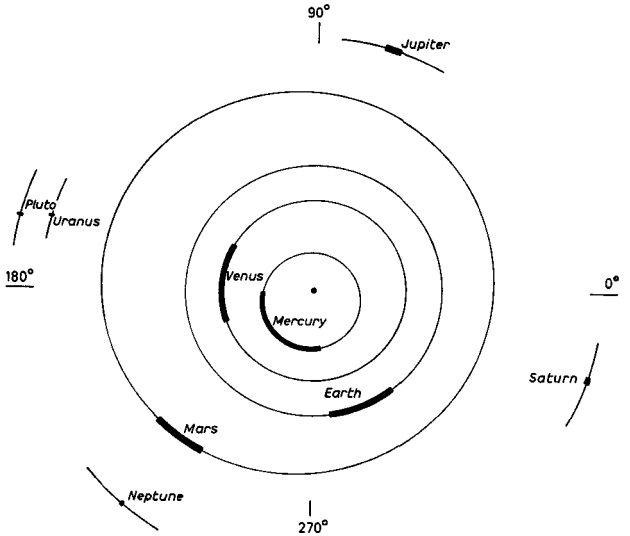
The magnitude of Mars. Mars is now well past opposition, and has receded from the Earth; its apparent diameter has become so small that no useful observations will be possible, with normal amateur telescopes, after the end of June. It is interesting to check the magnitude, and to note the gradual decrease. At the beginning of the month Mars will be considerably brighter than *Spica* in Virgo, but by the end of the month the two objects will be almost equal. They will, however, be rather difficult to compare, since the whiteness of *Spica* is so entirely unlike the strong red hue of Mars.

July

Full Moon: July 13 *New Moon:* July 28

Earth is at aphelion (farthest from the Sun) on July 3, when its distance from the Sun is 94,500,000 miles.

Mercury is at its greatest eastern elongation on July 18 (27 degrees, evening star), but it is then well south of the Sun, so that at sunset it is low in the sky, and lost in the bright evening twilight.



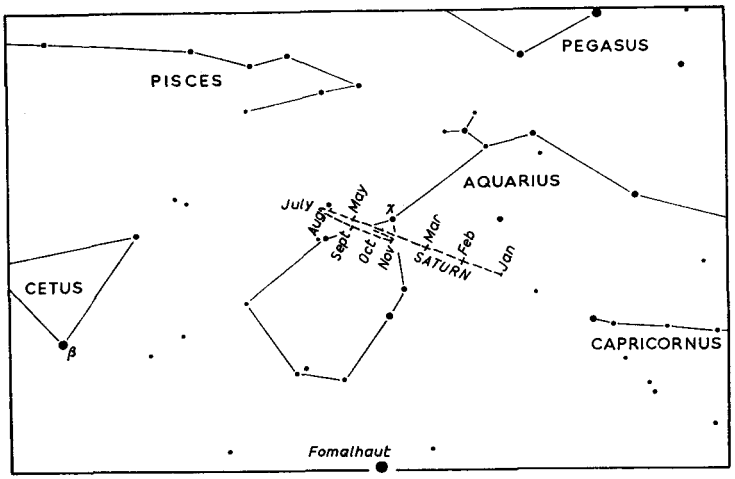
Planetary Orbits in July

Venus is a brilliant evening star (magnitude −3·3) to be seen in the western sky at sunset. As the planet moves out from the Sun, it also moves south, so that its altitude remains low, and it is a less conspicuous object than it can be at a more favourable elongation. Another result of the southerly motion is that the time of setting of the planet remains almost the same – about 1¼ hours after sunset – for several months. Venus passes rather more than a degree north of the star *Regulus* on July 24.

Mars is an evening star, but now sets before midnight. It is moving rapidly through Virgo towards the star *Spica*, and fades to magnitude +1·1 during the month.

Jupiter is a bright morning star, rising north of east in the early hours. It is now on the eastern borders of Taurus, moving away from the clusters of the Pleiades and Hyades, and becoming a little brighter (magnitude +1·5 to +1·6).

Saturn now rises in the east in mid-evening, and continues to grow brighter; by the end of the month it reaches magnitude +1·0. The star chart shows its position in relation to the stars of Aquarius.



Saturn, 1965

Conjunction of Venus and Regulus. As noted, Venus and Regulus are close together on July 24, the distance between the two being rather more than one degree. Occultations of bright stars by planets are excessively rare, but one such case did occur on 1959 July 7, when Venus occulted Regulus. The phenomenon took place in broad daylight, but was widely observed, and the dimming of Regulus as it passed behind the planet's atmosphere before being

hidden by the solid surface was timed. The results led to a derivation of the height of the obscuring atmosphere of Venus.

Occultations of planets by planets are even more rare, but they do occur now and then; for instance, Venus occulted Mars in 1590. However, no living observer is likely to see anything of the sort, since the next occasion will not be for some centuries to come!

Vega and Capella. Two of the brightest stars of the northern hemisphere are *Vega* and *Capella*; their only superior is *Arcturus*. (*Sirius*, of course, lies well south of the celestial equator.) *Vega* and *Capella* are almost equal at fractionally below zero magnitude, but are very different, *Vega* being of spectral type A (bluish) while *Capella* is a G-type yellow giant.

These are the only stars of great brilliancy which pass overhead in Britain. Moreover, they lie on almost exactly opposite sides of the Pole Star. When *Vega* is high up, *Capella* is low down, and vice versa; the zenith position taken by *Vega* during summer evenings is assumed by *Capella* during winter evenings.

Neither star actually sets in England, though both almost touch the horizon when at their lowest. From north Scotland, both are somewhat farther above the horizon when in the north. During July evenings *Capella* may still be made out, even though it is very low in the sky.

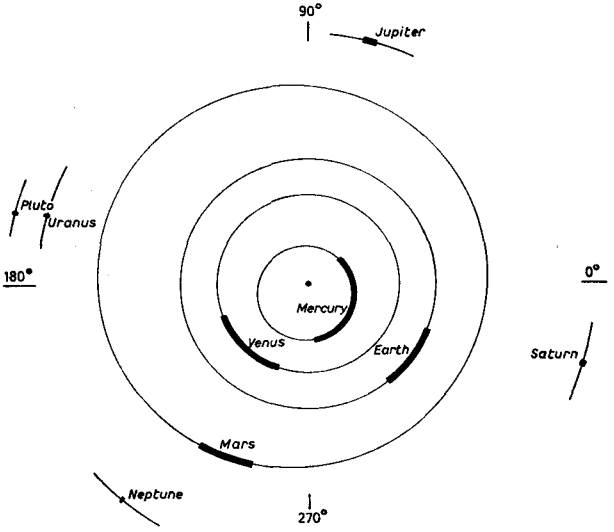
Beta Libræ. The Zodiacal constellation of Libra is not particularly distinguished, since its two brightest stars are only of the third magnitude. It was, however, one of Ptolemy's original 48 groups. Beta Libræ or *Zubenelchemali* has the distinction of being the only naked-eye star which is appreciably greenish in hue. This, at least, is what many textbooks say – but most observers will probably fail to detect any departure from the usual whiteness. However, it is interesting to look at the star through binoculars to see whether any slightly greenish tint is seen.

August

Full Moon: August 12 *New Moon:* August 26

Mercury is at inferior conjunction on August 15, and is not visible during the month.

Venus continues to move out from the Sun, and is a bright evening star, setting about 1½ hours after the sunset. The planet's apparent motion in the sky is quite rapid; it is interesting to note that it passes across the entire field of the chart on page 37 between July 15 and August 22. In the course of this journey it passes about half a degree north of Uranus on August 5.



Planetary Orbits in August

Mars is still to be seen as an evening star, moving rapidly to the east through Virgo. On August 8 it passes less than 2 degrees north of the star *Spica* on August 8, when planet and star are both of the same brightness (magnitude +1·2). Mars now sets in the early evening, about 1½ hours after sunset.

Jupiter is a morning star, rising at midnight in mid-August; it will be seen north of Zeta Tauri (see chart, page 54) at this time. It forms a striking configuration with the constellation Orion, and the other bright stars of the autumn sky. With the coming of the darker evenings the owner of a small telescope will find both interest and pleasure in watching the phenomena of Jupiter's satellites. The eclipses are the easiest to observe, but at the present time the outermost satellite Callisto passes either above or below the planet, without undergoing eclipse in its shadow.

Saturn rises in the east in the early evening, and is well up by midnight. It is approaching opposition, and growing noticeably brighter (magnitude $+1{\cdot}0$ to $+0{\cdot}8$). The rings of Saturn, as well as the largest satellite, Titan, may be seen in a small telescope.

The August Perseids. Of all the annual meteor showers that of the Perseids is much the richest and most spectacular. On a really dark, clear night during early August meteors are plentiful, and even the casual observer can hardly fail to notice them.

This, however, depends largely upon the absence of the Moon, and in August 1965 conditions will be unfavourable, since the Moon will be very much in evidence when the shower is at its peak. Even so, the brightest meteors should be seen without difficulty.

Before the war visual observations of meteors were carried on by many skilled amateurs, notably by men such as the late W. F. Denning. Then, however, radar methods of detecting meteor trails were developed, and it is probably true to say that the sheer visual method has by now lost much of its former importance. The meteor enthusiast is better advised to concentrate upon photography, particularly with regard to photographic spectra. This is a tedious business, and many hours of exposure are needed to capture even one meteor spectrum, but it is extremely valuable. Great patience is needed, and a complete year's work may end with no result whatsoever, but there is always a chance of providing something really spectacular. British amateurs such as H. B. Ridley, Director of the B.A.A. Meteor Section, have been to the fore in this branch of research.

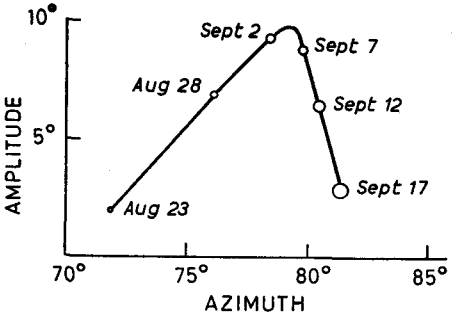
The W of Cassiopeia. Cassiopeia, a circumpolar constellation in Britain, is well placed during August, and it is worth examining two of its leading stars, Alpha (*Shedir*) and Gamma. *Shedir*, an orange giant of spectral type K, is of about the second magnitude; it has been regarded as an irregular variable of the *Betelgeux* type, though in the star catalogue drawn up by the Russian astronomer Kukarkin it is listed as constant. In any case, naked-eye estimates are of value. Gamma Cassiopeiæ, the middle star of the W, is undoubtedly variable, and is classed as a pseudo-nova. In 1936 it brightened up to magnitude 1·6, so that it exceeded the Pole Star; since then it has faded to about 2·5, though with marked fluctuations. It has an extraordinary spectrum which cannot be put into any ordinary type. Good comparison stars for both *Shedir* and Gamma are Beta Cassiopeiæ (magnitude 2·26) and Delta Cassiopeiæ (2·67).

Pallas. Pallas, the second minor planet in order of discovery, is also the second in order of size, since it is over 300 miles in diameter and is inferior only to Ceres. However, it never becomes bright enough to be seen without a telescope, and looks exactly like a star. It comes to opposition in early August, and lies in the small but easily found constellation of Delphinus (the Dolphin), which is situated in the region of Aquila and Cygnus.

September

Full Moon: September 11 *New Moon:* September 25
Equinox: September 23

Mercury is at greatest elongation west on September 2 (18 degrees) and at superior conjunction on September 27. In the early days of the month there is a very good chance of seeing this planet as a morning star. The diagram shows the changes in altitude and azimuth of Mercury on successive mornings when the Sun is 6 degrees below the horizon; this is about 35 minutes before sunrise at this time of year. The changes in brightness are roughly indicated by the sizes of the circles; it will be seen that Mercury is brightest after the date of western elongation.

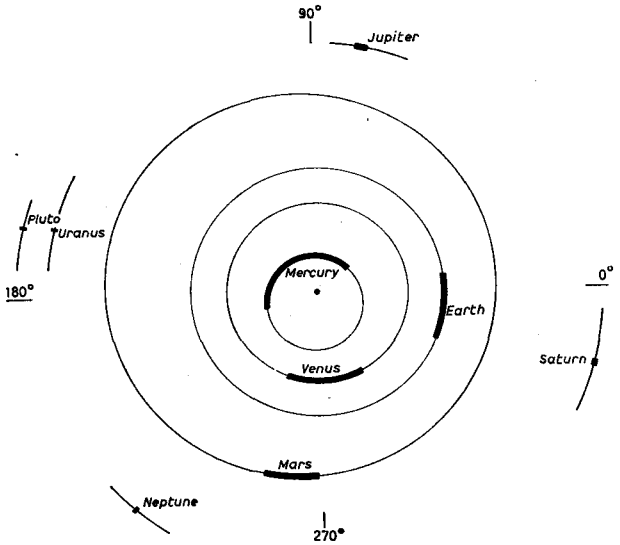


Mercury, September

Venus is an evening star, setting in the south-west about 1½ hours after the Sun. The planet passes about 2 degrees north of the star *Spica* on September 7 and continues to move rapidly eastwards, so that it will eventually overtake Mars.

Mars is also an evening star, moving eastwards through Libra; it will be 3 degrees south of Neptune on September 17. Mars continues to set about 1½ hours after sunset for some weeks, and remains of about the same brightness (magnitude +1·3).

Jupiter is a morning star, rising well before midnight, and passes from Taurus into Gemini at the end of September. Magnitude −1·8 to −1·9.



Planetary Orbits in September

Saturn is at opposition on September 6, at a distance of 806 million miles. As seen in the south at midnight, it is in a line with Alpha and Beta Pegasi (the right-hand side of the Great Square of Pegasus) and with *Fomalhaut*, well below it. Saturn is brighter than any of these stars (magnitude +0·8), but it can be much brighter than this if the rings are open wide. At this opposition the rings are tilted only about 4 degrees to the line of sight, the northern side of the rings being presented to the Earth and the Sun.

The rings of Saturn. Saturn, at opposition this month, has now moved into Aquarius, and although still south of the celestial equator is much better placed than has been the case for some years

past. To compensate for this, however, the rings are now closing, and will be edge-on to us in 1966.

The ring system is of tremendous extent, but is also very thin. Estimates of its breadth vary, but perhaps 10 miles is as good a value as any – which means that if Saturn is reduced in scale to the size of a tennis-ball, the rings will be much thinner than a sheet of stamp-paper. They are not solid or liquid sheets, and, in fact, no rings of this sort could exist, since the entire system lies within the Roche limit for Saturn and would be immediately disrupted by the planet's powerful gravitational pull. The rings are made up of large numbers of small particles, perhaps ices or ice-coated, moving round Saturn in the manner of dwarf moons.

The most celebrated division, Cassini's, separates the two main rings (A and B), and is easy to see with a small telescope when the system is well displayed, though in 1965 it will be much more difficult. The outer ring (A) is also said to have a division, Encke's. Minor divisions have been reported elsewhere, but seem to be more in the nature of 'ripples' than true gaps, and will certainly not be seen in 1965.

From 1909 onward there have been many reports of another dusky ring (D) outside the main system. This has not been confirmed, however, and its existence is dubious in the extreme, though there is no theoretical objection to it.

Ceres. Ceres, the largest member of the asteroid swarm, has a diameter of 430 miles. It comes to opposition in September, and is situated in Cetus. However, its brightness will not exceed magnitude 7·3; it will be invisible to the naked eye – in fact, it never attains naked-eye visibility – and the only way to tell it from a star is to chart its position over several nights, noting its shift.

Fomalhaut. *Fomalhaut*, in Piscis Austrinus (the Southern Fish), is the southernmost of the first-magnitude stars visible in Britain. It is 24 light-years from us; of the first-magnitude stars, only Alpha Centauri (4·3 light-years), *Sirius* (8·6), *Procyon* (10) and *Altair* (16) are closer. *Fomalhaut* has an A-type spectrum, and is 13 times more luminous than the Sun.

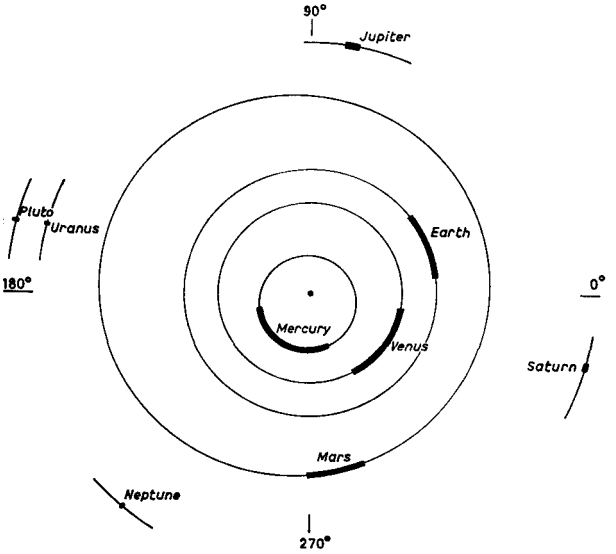
From south England it may be quite prominent during autumn evenings, when it will be found below the Square of Pegasus. From north Scotland, however, *Fomalhaut* barely rises above the horizon, and never becomes at all conspicuous. The little constellation of Piscis Austrinus contains no other bright stars.

October

Full Moon: October 10 *New Moon:* October 24

Mercury was in conjunction at the end of September, and is too close to the Sun to be seen during the month of October.

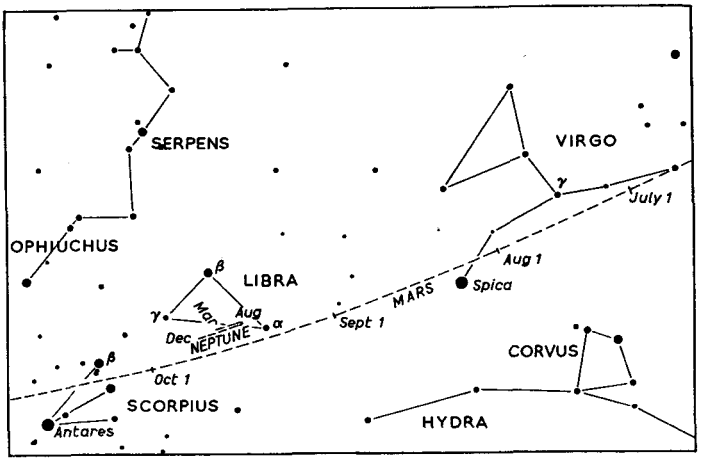
Venus continues as an evening star, and reaches its greatest latitude south at the end of the month. It then begins to move north again, and so becomes more favourably placed; by the end of October it sets nearly 2 hours after the Sun, and its brightness increases to magnitude −3·9. Venus passes about 2 degrees north of the star *Antares* on October 17, and overtakes Mars on October 19, passing less than 2 degrees south of that planet.



Planetary Orbits in October

Mars may still be seen as an evening star of the first magnitude, setting in the south-west about 1½ hours after sunset. It is moving rapidly through the northern part of Scorpius, and passes 4

degrees north of *Antares* on October 16. At this time *Antares* (the 'Rival of Mars') will be a little brighter than the planet, but comparison of the colours of the two objects should be interesting. Mars is overtaken by Venus on October 19, and the two planets will form an interesting groups with the bright stars of Scorpius. Added interest will be given to the picture on the night of October 27, when the young crescent moon will be close to Mars.



Mars and Neptune

Jupiter is also an evening star and now rises in mid-evening to the north of east. On October 19 it reaches a stationary point on the western borders of Gemini, near the two stars Mu and Eta. Jupiter is now a little brighter (magnitude −1·9 to −2·1) as it approaches opposition.

Saturn is now to be seen in the south in mid-evening, and sets in the west in the early hours of the morning. It is still moving retrograde in Aquarius, and fades a little during the month (magnitude +0·8 to +1·0).

October the fourth. October 4 is an important date in the history of space research. In fact, it may be said that the Space Age

opened on 1957 October 4, when the Russians launched the first artificial satellite – Sputnik I. It is amazing to reflect how great have been the advances since that event, only 8 years ago. At the time, there was considerable surprise in western Europe and in America, since the Russians had said very little about their rocket programme and nobody outside Soviet territory knew how much progress they had made.

Two years later, on 1959 October 4, the Russians set up their Moon probe Lunik III, which represented the greatest triumph in space research up to that moment. Lunik III made a trip round the Moon, and sent back photographs of the averted side, proving once and for all that the Moon's hidden regions are basically similar to those which we have always known (even though there seem to be fewer of the dark seas or *maria*). It will be interesting to see whether 1965 October 4 coincides with another spectacular Soviet launching!

The Seven Sisters. Of all open clusters that of the Pleiades or Seven Sisters is much the most prominent. There is a certain amount of interest in finding out how many stars in the group may be seen without optical aid under good conditions. The record is said to be held by a last-century German observer, E. Heis, who claimed to have seen no less than 19. However this may be, people with average eyesight can see 7 stars, while those with exceptionally keen sight may glimpse as many as 11 or 12.

The Square of Pegasus. Pegasus, the Flying Horse, is one of the leading autumn constellations, and is easy to identify. For some obscure reason one of the Square stars, *Alpheratz*, is no longer included in Pegasus; it was formerly known as Delta Pegasi, but has now been transferred to Andromeda as Alpha Andromedæ.

Pegasus is not a rich constellation so far as faint stars are concerned, though its outline is distinctive. On a dark, clear night it is interesting to see how many stars you can see inside the Square; there will not be very many of them.

Beta Pegasi or *Scheat*, the upper right-hand star of the Square, is an interesting Red Giant variable. Its magnitude ranges be-

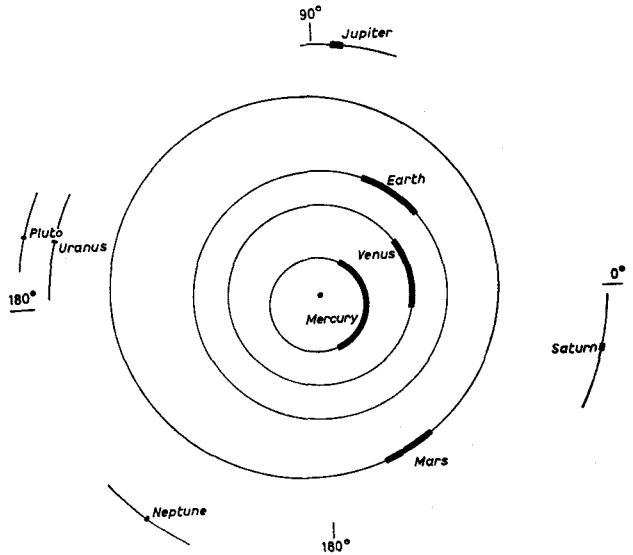
tween $2\frac{1}{4}$ and $2\frac{3}{4}$, and there is a very rough period of about 40 days. Good comparison stars are Alpha Pegasi (magnitude 2·50), Gamma Pegasi (2·84) and Alpha Andromedæ (2·06), the other three stars of the Square. *Scheat* is a fine sight in a low-power telescope, since its orange hue is well brought out.

November

Full Moon: November 9 *New Moon:* November 23

Mercury is at its greatest eastern elongation on November 13 (23 degrees, evening star), but it is then well south of the Sun and will not reach a sufficient altitude to be seen after sunset.

Venus is at greatest eastern elongation on November 15 (47 degrees, evening star). In a small telescope it then has the same appearance as the Moon at first Quarter. Although well out from the Sun, Venus is nearly 27 degrees south of the equator in early November, and is therefore low in the south-western sky at sunset. By the end of the month it will set about 3 hours after the Sun, and will have reached a magnitude of −4·2.



Planetary Orbits in November

Mars is an evening star, setting nearly two hours after the Sun. It is now moving rapidly through Sagittarius, far south of the equator and therefore very low in the sky in the south-west.

Jupiter rises in the early evening and continues to increase in brightness (magnitude −2·2 to −2·3). Its retrograde motion carries it back into Taurus, a little to the north of its previous path (see star-chart on page 54).

Saturn may be seen in the south-west as soon as it is dark; it sets about midnight at the end of November. The planet reaches a stationary point on November 14 near the fourth-magnitude star Chi Aquarii; it then begins to move direct again, and fades a little to magnitude +1·1.

An annular eclipse of the Sun on November 23 is visible only in southern Asia and Australia. See page 80.

Annular eclipses of the Sun. When the Sun, Moon and Earth are exactly lined up, with the Moon near apogee, the apparent diameter of the Moon is slightly less than that of the Sun. Consequently, not all the solar disk is covered, and a ring of sunlight is left showing round the dark body of the Moon, producing an annular eclipse (Latin *annulus*, a ring).

Annular eclipses are interesting, but in importance they cannot be compared with total eclipses. The slightest sliver of the bright Sun is enough to drown the solar atmosphere (the corona and chromosphere), which cannot therefore be seen at annular eclipses. It is not likely that any full-scale expeditions will be made to India or Thailand to observe the eclipse of November 23.

It may be worth listing the next few annual eclipses:

1966 May 20, $9^h\ 43^m$ (mid-eclipse). Partial (phase 0·5) in England. There may be a very short totality in parts of Greece, but elsewhere along the central line – North Africa, parts of the U.S.S.R., etc. – the eclipse will be annular.

1969 September 11 ($19^h\ 56^m$). Annular in the North Pacific and parts of South America.

1970 August 31 ($22^h\ 2^m$). Annular in the South Pacific.

1972 January 16 ($10^h\ 53^m$). Annular in Antarctica.

The next total eclipse visible anywhere in Eurasia will be that of 1968 September 22, which will be seen from parts of North

Russia. Britain must wait until 1999 August 11 for its next total eclipse; the track will then cross Cornwall.

The Surface of Jupiter. Jupiter, the Giant Planet, is now coming into view in the early evening, and will reach opposition in December. It is in Taurus, well north of the celestial equator and so excellently placed for observation.

In 1962, 1963 and 1964 Jupiter's aspect was most unusual, since the two main belts (the North Equatorial and the South Equatorial) appeared to merge into one continuous band. The Great Red Spot, well to the south of the equatorial zone, was very much in evidence, and was decidedly pink. The reasons for this dramatic change are still not known, but it is unlikely that the change itself will be anything but temporary, and by 1965 Jupiter may well have returned to its conventional aspect.

Jupiter is probably the most rewarding planetary object for the amateur observer. It is very useful to take transits of surface features – that is to say, the times when these features are brought to the central meridian by virtue of the planet's rotation. A 6-inch telescope is adequate for this work, though 8 or 12 inches is naturally better.

In 1956 it was found that Jupiter is a source of radio waves. For some time it was believed that these emissions might be associated either with phenomena of the thunderstorm variety on Jupiter, or else with certain specific features such as the Great Red Spot, but it now appears much more likely that they are not genuine Jovian emissions at all; F. W. Hyde considers that they originate in the Sun, and are sent back to us by way of the Jovian ionosphere. This view seems to be supported by the weight of evidence, though it is perhaps too early to claim that the question has been definitely settled.

Aries, the Ram. Aries is celebrated as being the first constellation of the Zodiac. It is not, however, very conspicuous. It is not hard to find; it lies below Andromeda, and the pattern of three moderately bright stars is easy to identify. The leader, *Hamal* (Alpha Arietis), is of the second magnitude. Gamma Arietis, the faintest

of the three, is a wide, easy double with almost equal components.

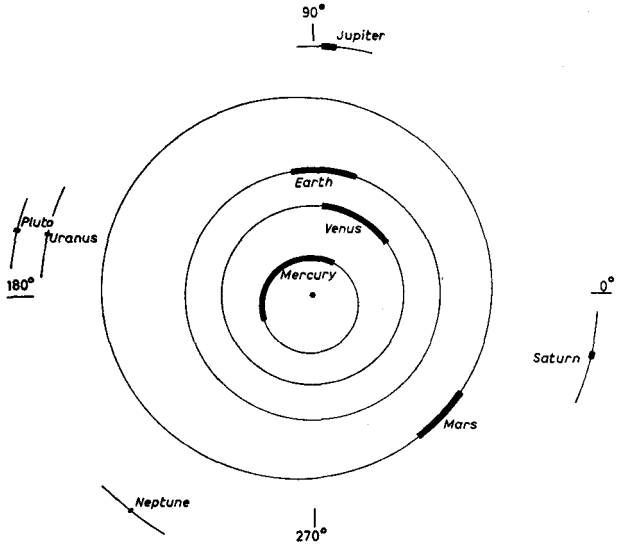
Strictly speaking, Aries is now the last Zodiacal constellation instead of the first, since the vernal equinox has now been shifted, by precession, into the neighbouring constellation of Pisces; however, the old name of the 'First Point of Aries' has been retained. In mythology, Aries was the ram with the golden fleece, which carried the two children Phryxus and Helle across the Hellespont; Phryxus reached safety, but Helle fell into the sea and was drowned – hence the name of the Hellespont itself.

December

Full Moon: December 8 *New Moon:* December 22
Solstice: December 22

Mercury is at inferior conjunction on December 3, but will reach its greatest western elongation on December 21 (22 degrees, morning star). It is then well north of the Sun, and may, perhaps, be seen in the south-east after dawn at a low altitude.

Venus is at its greatest brilliancy as an evening star on December 21 (magnitude −4·4). The Sun is at its farthest south on December 22, and Venus, well to the east, is therefore farther north and more favourably placed. As a result, it sets in the south-west more than 3 hours after the Sun.



Planetary Orbits in December

Mars is an evening star (magnitude +1·4) setting about 2 hours after sunset; it forms a pleasing group with the stars of Sagittarius

at the beginning of the month, and then moves into Capricornus. There is no opposition of Mars in 1966, the next one occurring in April 1967, when the planet will be in the constellation Virgo.

Jupiter is at opposition on December 18, magnitude −2·3. This is a very favourable opposition of this planet, which is now at its greatest declination north. By the end of December, Jupiter will again be seen near the star Zeta Tauri and the Crab Nebula M1, but this time it is a little farther north than it was in August. The next opposition of Jupiter occurs in 1967 January.

Saturn is an evening star, setting in mid-evening in the west. It continues to fade, reaching magnitude +1·3 at the end of the year. The next opposition of Saturn occurs in 1966 September.

A penumbral eclipse of the Moon will take place on December 8 – see page 80.

The surface of Venus. Venus, now a glorious object in the evening sky, may even be brilliant enough to cast shadows; it cannot possibly be mistaken, since it is far brighter than any other object in the the night sky. It is a full two magnitudes superior to its nearest rival, Jupiter, and three magnitudes brighter than Sirius.

Until 1962 almost nothing was known about the surface conditions on Venus. The planet is permanently veiled by its obscuring atmosphere, and different authorities held different views; according to F. L. Whipple and D. H. Menzel, for instance, the clouds were made up of H_2O, and the surface was almost or entirely covered with ocean, while others held that Venus must be an arid dust-desert. The first positive information was sent back by the U.S. rocket Mariner II, which passed within 25,000 miles of Venus on 1962 December 14, and was in radio contact during its time of closest approach. If the Mariner results are to be trusted, then Venus is overwhelmingly hostile, with a surface temperature of at least 800°F. At this temperature, needless to say, no liquid water could exist.

Doubts have been expressed. For instance, it has been pointed out that the Mariner instruments were designed to function at a

distance of less than 10,000 miles from Venus, whereas they were actually used at more than double this range – with an inevitable reduction in accuracy. However, the evidence, as it stands, is that Venus really is extremely hot, and presumably quite lifeless.

The Heavenly Twins. *Castor* and *Pollux* in Gemini (the Twins) are very prominent during the winter season, and make a pair which may be identified without the slightest difficulty. *Pollux* is appreciably the brighter of the two; its magnitude is 1·16, whereas that of *Castor* is only 1·61. Ptolemy, 2,000 years ago, made *Castor* the brighter, and this was also stated by the later Arab astronomer Al-Sûfi. It may be, then, that *Castor* has faded (or that *Pollux* has increased in brightness); on the other hand, the old magnitude estimates were decidedly rough, and it would be unwise to put too much faith in them.

Castor is, in fact, a complex system. It is a splendid binary, the components being of magnitudes 1·97 and 2·95. Many textbooks say that it is separable with a very small aperture; this was true once, but is no longer so. The orbital motion of the pair has caused a very marked closing-up, and *Castor* cannot now be properly split except with a telescope of some power. Each component is a spectroscopic binary.

At an apparent distance of 78 seconds of arc lies Castor C, otherwise known as YY Geminorum, an eclipsing binary system made up of two Red Dwarfs. Altogether, then, *Castor* consists of six suns, four bright and two dim, so that it makes up what may be called a 'stellar family'.

Mythologically, Castor and Pollux were twin brothers; Pollux was immortal, while Castor was not. When the inevitable happened, and Castor was killed, Pollux was so heartbroken that he asked permission to share his immortality with his brother, whereupon Jupiter, King of the Gods, placed both boys in the sky.

Gemini is a very rich constellation, well worth sweeping with a low power. It contains several other bright stars, notably the second-magnitude *Alhena* (Gamma Geminorum) which lies roughly between *Pollux* and *Betelgeux*. There are all manner of

interesting telescopic objects, and the Milky Way flows right through the constellation. It is interesting to note, as a coincidence, that of the three planets discovered since ancient times, two (Uranus and Pluto) were located while in Gemini.

The area bounded by imaginary lines joining *Sirius* in Canis Major, *Procyon* in Canis Minor, *Betelgeux* in Orion and *Alhena* in Gemini is occupied by a 'modern' constellation, Monoceros (the Unicorn). It contains no star brighter than the fourth magnitude, and has no distinctive pattern, but it is quite rich in faint stars, and it, too, is worth sweeping with a low power.

Eclipses, 1965

In 1965 there will be three eclipses, two of the Sun and one of the Moon. There is also a penumbral eclipse of the Moon.

1. *A total eclipse of the Sun* on May 30, visible only in the Pacific Ocean. The path of totality begins at the extreme north of the North Island of New Zealand, and crosses the Pacific Ocean to end at sunset on the western coast of Peru. Maximum duration $5^m\ 16^s$.

2. *A partial eclipse of the Moon* on June 14, visible in the British Isles. This eclipse is the second of a series, the first of which occurred in 1947, and it is therefore of small magnitude, only 18 per cent of the Moon's face being covered by the Earth's shadow. The shadow will first be seen at the upper left-hand edge of the Full Moon just after midnight (at $00^h\ 58^m$) and will reach a maximum at $1^h\ 49^m$. The eclipse ends at $2^h\ 40^m$.

3. *An annular eclipse of the Sun* on November 23, visible only in southern Asia. The path of the eclipse crosses northern India, Thailand and New Guinea, and has a maximum duration of nearly 4 minutes. A partial eclipse of the Sun will be seen in Australia and in most of Asia.

4. *A penumbral eclipse of the Moon* on December 8 begins at $15^h\ 08^m$ (just before moonrise) reaches a maximum (91 per cent of the Moon being covered) at $17^h\ 10^m$, and ends at $19^h\ 13^m$. In a penumbral eclipse the change in the Moon's light is very small, and the phenomenon is unlikely to be seen with the naked eye.

Occultations

In the course of its journey round the sky each month, the Moon passes in front of all the stars in its path, and the timing of these

occultations is useful in fixing the position and motion of the Moon. The Moon's orbit is tilted at more than 5 degrees to the ecliptic, but it is not fixed in space. It twists steadily westwards at the rate of about 20 degrees a year, a complete revolution taking 18·6 years, during which time all the stars that lie within about 6½ degrees of the ecliptic will be occulted. The occultations of any one star continue month after month until the Moon's path has twisted away from the star, but only a few of these occultations will be visible at any one place in hours of darkness.

There are only four first-magnitude stars that can be occulted by the Moon; these are *Regulus*, *Aldebaran*, *Spica* and *Antares*. In 1965, however, the Moon's path is in such a position that it passes north of all four stars, and they cannot therefore be occulted.

The planets Mercury, Venus, Mars and Jupiter are all occulted by the Moon in 1964, but these phenomena will not be visible in the British Isles.

The planet Neptune is also in such a position that close conjunctions with the Moon occur each month in 1965. Neptune is too faint, however, for these phenomena to be of interest to the casual observer.

Details of occultations of the planets, and of all stars down to magnitude 7·5, as well as possible occultations of stars by planets, are published in the annual *Handbook* of the British Astronomical Association.

Comets in 1965

The appearance of a bright comet is a rare event which can never be predicted in advance, because this class of object travels round the sun in an enormous orbit with a period which may well be many thousands of years. There are therefore no records of the previous appearances of these bodies, and we are unable to follow their wanderings through space. The comets of short period, on the other hand, return at regular intervals, and attract a good deal of attention. Unfortunately they are all faint objects, and are

recovered and followed by photographic methods, using large telescopes. Most of these short-period comets travel in orbits which carry them out to the orbit of Jupiter, and it is this planet which is responsible for the severe perturbations which many of these comets undergo. In 1965 the following short-period comets are expected to return to perihelion:

Comet Wolf-Harrington is a faint comet with a period of 6½ years and an orbit of moderate eccentricity. It was discovered in 1925 and subsequently lost; in recent years, however, it has been shown to be identical with a comet discovered by Harrington at Mount Palomar Observatory in 1951. It was recovered in 1957, and is expected again in 1965 February.

Comet Reinmuth (1) is expected to return at the end of the year. It has a longer period (7·6 years), and was discovered in 1928. Although it was seen again in 1935, it was missed at the 1942 return, probably because of errors in the prediction. A recalculation was made, and the comet was successfully recovered in 1950 and 1958. Owing to planetary perturbations, the orbit, which has a moderate eccentricity and a small inclination, is becoming larger and less eccentric.

Comet Giacobini-Zinner is not due to return to perihelion until the beginning of 1966, but it will probably be detected before that. This comet was discovered in 1900, and has been seen at seven returns. It has an eccentric orbit with a period of 6½ years, and an inclination of about 30 degrees. It is this comet which is responsible for the Draconid shower of meteors of October 9, which gave such fine displays in 1933 and 1946 – the latter being one of the first meteor showers to be studied by radar methods. A recent numerical study of the past history of this comet shows that the meteors arose from material ejected from the head of the comet shortly after the perihelion passage of 1894.

Comets Schwassmann-Wachmann (1) and *Oterma* are visible every year because they travel round the Sun in orbits which are much more nearly circular than those of most other comets. Comet Schwassmann-Wachmann has an orbit with a period of 16 years which lies entirely between the orbits of Jupiter and Saturn.

It undergoes remarkable changes of brightness, which seem to have some connexion with solar activity. Comet Oterma has a smaller orbit, lying between those of Mars and Jupiter, and resembling the orbits of certain minor planets. The period at present is nearly 8 years, but Miss L. Oterma has shown that the comet made a close approach to Jupiter in 1962–64, and this caused the orbit to become much larger and more eccentric, with a period of 19 years. As a result the comet will only be visible in large telescopes in future years, because its perihelion distance will have increased from 3·4 to 5·3 astronomical units.

Meteors

Meteors ('shooting stars') may be seen on any clear moonless night, but on certain nights of the year their number increases noticeably. This occurs when the Earth chances to intersect the orbit of a meteor swarm, which is a concentration of meteoric dust moving in an orbit around the Sun. Such an intersection can occur only at one particular time of year, but if the dust is spread out along the orbit, the resulting shower of meteors may last for several days. The word 'shower' must not be misinterpreted – only on very rare occasions have the meteors fallen so fast as to resemble snowflakes falling.

The naked-eye study of meteors is quite a laborious task, but even a casual observer, watching for, say, ten minutes on an August night, may observe a number of Perseids. If their tracks are marked on a star map, and traced backwards, a number of them will be found to intersect in a point (or a small area of the sky) which marks the radiant of the shower. This gives the direction from which the meteors have come.

The following table gives some of the more easily observed showers, with their radiants; the effect of moonlight in 1965 is indicated.

Limiting dates	*Shower*	*Maximum*	*R.A.*	*Dec.*	*Note*
Jan. 3–4	Quadrantids	Jan. 3	$15^h\ 28^m$	$+50°$	
April 20–22	Lyrids	April 22	$18^h\ 04^m$	$+33°$	
July 27–Aug. 17	Perseids	Aug. 12	$3^h\ 04^m$	$+58°$	M
Oct. 15–25	Orionids	Oct. 20–21	$6^h\ 24^m$	$+15°$	
Oct. 26–Nov. 16	Taurids	Nov. 1–7	$3^h\ 36^m$	$+14°$	M
Nov. 15–17	Leonids	Nov. 16	$10^h\ 08^m$	$+22°$	M
Dec. 9–14	Geminids	Dec. 13	$7^h\ 28^m$	$+32°$	
Dec. 20–22	Ursids	Dec. 22	$14^h\ 28^m$	$+76°$	

M=moonlight interferes

Minor Planets in 1965

Of the 1,600 planets which are listed in the catalogues, only the 'big four', Ceres, Pallas, Juno and Vesta, can reach any considerable brightness, and only the last of these, Vesta, can occasionally be seen with the naked eye. In 1965, however, Vesta is of magnitude 6·6 when at opposition on December 28, in the constellation Gemini.

The planets Pallas and Juno both come to opposition in early August, but are widely separated in the sky, Pallas being well north in Delphinus, while Juno is on the borders of Aquila and Aquarius. Ceres is at opposition in September in Cetus, and at this time may reach the seventh magnitude.

Some Events of 1966

ECLIPSES

In 1966 there will be two eclipses of the Sun and two penumbral eclipses of the Moon.

May 4 – a penumbral eclipse of the Moon;
May 20 – an annular eclipse of the Sun, visible in northern Africa, southern Europe and Asia;
Oct. 29 – a penumbral eclipse of the Moon;
Nov. 12 – a total eclipse of the Sun, visible in the eastern Pacific Ocean, central and south America, the southern Atlantic Ocean and South Africa.

THE PLANETS

Mercury may be seen as an evening star at the time of eastern elongation on March 5, and as a morning star about the time of western elongation on August 16.

Venus will be at inferior conjunction on January 26, and will then become a morning star until superior conjunction on November 9; it will be at greatest western elongation on April 6.

Mars will be an evening star until conjunction on April 29, after which it will be a morning star; there is no opposition of Mars in 1966.

Jupiter is at conjunction in July 5, and there is no opposition during the year; the planet will be an evening star for the first half of the year, and a morning star in Gemini after conjunction.

Saturn will be in conjunction on March 10, and at opposition on September 19 in Pisces.

Uranus and *Pluto* will both be at opposition on March 8 in Leo; *Neptune* is at opposition on May 12 in Libra.

PART TWO

Article Section

In each *Yearbook* we do our best to present a varied selection of articles, so that even if we cannot satisfy everybody there is at least something to interest everybody. This policy has been continued in the present issue. G. A. Hole, who has an international reputation in optics and who is Director of the Instruments and Observing Methods Section of the British Astronomical Association, has written at some length about those irritating telescopic faults which plague all amateurs and, incidentally, all professionals; he has some sage advice to offer, and makes some original suggestions. Since Mars will come to opposition early in 1965, and will attract much attention, it seemed only fitting to include a specialist article, written on this occasion by Professor S. Miyamoto, Director of the Kwasan Observatory in Kyoto, Japan; in addition to his astrophysical work, Professor Miyamoto is famed for his lunar and planetary studies, and has paid particular attention to Mars. As a preface, I have added a short 'Introduction to Mars'. Meteoritic craters, also very much in the news, are described by Howard Miles, Director of the Artificial Satellite Section of the British Astronomical Association. This is the International Year of the Quiet Sun, and F. W. Hyde, who is taking an active part in the programme from his radio-astronomy observatory at St Osyth, has presented the latest research into this aspect. In astronautics, we have a contribution from K. W. Gatland, Vice-President of the British Interplanetary Society; Henry Brinton has written about measuring the universe, while for those attracted by astrophysics we have an article by Brian Warner of the University of London Observatory, who has recently been carrying out research in Pretoria and who has made a special study of these cool late-type stars described in the article.

Perhaps not all these topics will concern you; but you will, we hope, be interested in what our team of article-writers has to say.

Telescopic Faults

G. A. HOLE

The performance of a telescope always falls short of perfection – for many reasons, only some of which are capable of remedy by the user.

The first category starts with high-altitude atmospheric disturbances, both mechanical movements of air-masses in vast high-speed streams, and closer temperature differences in the air intervening between the object being observed and the telescope itself. These disturbances result in unequal refraction, regular or irregular as the case may be, of the incoming beam of light – which thus enters the telescope in anything but the parallel homogeneous stream for which the object-glass was fashioned. (Of course, the same trouble applies to reflectors.) If the eyepiece is removed, and the light from the object-glass received direct into the eye, the illuminated disk of the object-glass is seen, with the signature of any atmospheric oddities clearly shown thereon. One soon learns what to expect from the results of such an inspection.

There are, however, many other reasons why a telescope gives less than its best performance. These fall into two main classes: faults of construction, and faults of adjustment. The first is remedial only on a long-term basis, but the second may be eliminated by immediate action.

Spherical aberration, which prevents a sharp focus from being obtained, is caused by differences of focal length resulting from errors on the surface of the objective. In a refractor, these errors of shape may be on any of the four surfaces, and optical treatment is needed to locate and correct them. The same sort of trouble in a reflector must have its origin on the single surface of the mirror. Generally, the particular fault is easily seen by examining the

cone of light, with the eyepiece alternately inside and outside focus. The expanded images (extra-focal disks) as seen should be exactly alike as to the distribution of light across them. If unequal in this respect, a lack of correction (or existence of spherical aberration) is indicated. Should the inside focus section show a dark centre it means that the light that should be present is focusing long (under-correction); the outside-focus sector will show the misplaced light as a brighter centre, because this outside focus section is closer to the focus of the aberrant light. The reverse is the case with an overcorrected optical system. This test should be carried out at various equal distances each side of the focus, and becomes more stringent the closer to focus it is applied. An eyepiece of good quality should be used, as any lack of correction of the eyepiece will also show up.

The reflector has a powerful test for perfect correction already 'built in', as the presence of the secondary mirror (flat, Cassegrain or Gregorian) means that the incoming beam has its centre blocked out, and is therefore hollow. After reflection, this beam becomes a tapering cone of light, and the central 'core of darkness' ceases to exist at the focal plane; it diverges with the light after focus, and shows in the extra-focal sectors as a central black spot. Only with a perfectly corrected mirror does this black spot appear the same size and intensity at equal distances on either side of focus. At positions only just out of focus, the spot will have vanished on one side or the other, depending on whether the aberrant light filling it in happens to be of long or short focus.

In a reflector, these appearances are without false colour. A refractor shows uncorrected colour around the actual image, generally of a faint violet tint, and its extra-focal sectors show, respectively, a purple edge inside focus and a green edge outside focus. Also, of course, there is no central black spot. Anything found to be amiss with the corrections is a matter for an optical expert, as it is not adjustable.

While spherical aberration is one cause of poor performance, it is not the most prevalent. When it exists it is generally in a symmetrical form, and under adequate tests cannot escape notice

unless it is very minor. Its effect is to make the eye seek the smallest part of the focal cone, and accept that as the focal plane. While magnifying powers are kept low to moderate (up to 250 or 300) the definition is unlikely to be too bad. Should astigmatism be present, there is no true focal plane at all; the smallest diameter of the focal cone is, or can be, much larger than when slight correction errors exist by themselves – so that there is no proper definition in the image even when focused down to its tightest point. Close examination of the *shapes* of the extra-focal sectors will make the situation clear; for a good mirror, the images should, of course, be circular. (For correction checking, on the other hand, it is the intensity distribution of the light which matters.) Again, the closer to the focus, the more stringent the test; even a badly astigmatic cone of rays will appear circular if it is examined far enough from the focus. As focus is approached, the sector takes on an elliptical outline, in bad cases narrowing down until it is almost a line instead of a circle. The long axis of the ellipse rotates through 90 degrees as the cone passes through focus, or, more accurately, the position of least confusion – since no actual focal plane can exist when different diameters of the mirror or object-glass focus in different planes.

The reflector can exhibit this fault even when its mirror is beyond reproach, as any departure from optical flatness in the diagonal, placed as it is at an angle, is unsymmetrically exaggerated, and the previously circular cone produced by the main mirror becomes astigmatic. This is the case with a flat which is concave or convex. If it is irregular, the reflected cone is also irregular, and once again there is no true focus.

With a well-marked case of astigmatism, the offending unit may be identified by rotating the main mirror. If the astigmatism rotates also, then it belongs to the mirror. Should the astigmatism remain unaltered, then it must be the flat that is at fault, and should therefore be replaced or re-worked.

When astigmatism is found in the image given by a refractor it may sometimes be reduced, or even eliminated, by rotating the flint-glass and crown-glass components of the objective until the

'best' position is found; the edges of the lenses should then be marked. This is possible if both flint and crown lenses are astigmatic, when rotating the components can afford some degree of compensation, but if only one component is at fault the method is of no use. Should the optical axes of the two lenses of the objective fail to coincide, then unsymmetrical colour will show around the image at focus; one component must be displaced sideways on the other until the condition is rectified, if necessary machining out the cell to permit this. The fault arises from either faulty edging of the lenses, or excessive clearance in the cell.

Should the mirror or objective suffer from flexure, the cone of light from it will be non-circular, regular or irregular in outline according to whether the flexure is regular or not. Two factors apply here. If the flexure is caused by deformation of the mirror or lens by faulty support or floatation, or by pinching of the glass in its cell, the remedy is obvious. However, should the glass in question have been improperly mounted during its manufacture, so that it has been worked in a flexed condition, the flexure will be permanent; only re-working can eliminate it, and this is a matter for an expert.

The eyepiece tests described here should be applied to axial images only, with the image being brought to the centre of the field. The quality of off-axis images depends on the types of optics in the objective itself, and is not subject to any adjustment. Generally, the images will be found to become progressively more comatic as they depart from the axis. The appearances given above are true faults if observed in an instrument that is in correct adjustment, but careful adjusting is essential before testing, since errors of tilt (squaring-on) in the mirror or objective may produce very similar effects. The first step, then, is to see that everything is properly squared-on, as otherwise the extra-focal images will not be circular whatever the quality of the optical system itself. Precisely at focus, the image of a star will show a flare, and the adjustment consists of using the tilting screws, with which all mirrors and objectives should be equipped, in order to 'tuck in' this flare.

First, the extra-focal sections may be examined to see if the central black spot is, in fact, anywhere near the centre. Tilt the object-glass or mirror until it is; then go closer to focus and repeat the process, refining the adjustment each time, until at focus the image is as round and as free from spikes and flares as possible. The optics may then be assessed for the various faults described above. When dealing with a refractor, it is a great help to 'manufacture' a central black spot by fitting a central mask to the objective, about one-fifth of its aperture in diameter.

Peculiar to the refractor image is its halo of uncorrected colour. This should be unobtrusive, and at a minimum at the focus, where it ought to be a faint violet or purple hue. The cone of rays inside focus should have a purple edge, with a green edge outside focus. Defective colour correction shows as a variation from these appearances. In cases where definite colour error is established, it sometimes helps to increase the separation between the lenses. This must affect the corrections for spherical aberration, and may impair the performance in this respect even though it reduces the false colour.

Should the colour error be of the wrong sign to improve with separation, the rear surface of the flat component will need to be altered, and this, unfortunately, must be carried out by an optical expert. As with spherical aberration, the residual colour may be reduced by use of an eyepiece of opposite sign, but complete compensation is unlikely.

Final touches to the squaring-on must be carried out after dark on an actual star image. Approximate adjustment can be achieved during daylight by using the turning screws so as to make everything concentric. With the eyepiece removed, and replaced with an eye-centring disk (a low-power eyepiece with its lenses taken out will do), the eye is positioned centrally at one end of the draw-tube. The inner end may be fitted with crossed strings, thus defining its axis; alternatively, the profile of the inner end may be used. The diagonal flat mirror should be in the centre of the main telescope-tube, and needs to be brought along the tube until it is nicely centred when seen through the sight-equipped eye-tube. It

must then be tilted until the reflected picture of the main mirror is also nicely centred on its surface. This appearance is sensitive to the flat tilting screws, and these only. Once the flat appears to look squarely at the main mirror, it may be forgotten. Nothing more need be done to it during the rest of the adjustment.

The second stage of the approximation is to tilt the main mirror until the reflection of the diagonal is central to the reflection of the main mirror. This may be facilitated by placing, on the face of the main mirror, a card mask, with a central hole about 1 inch greater in diameter than the minor axis of the diagonal. This, in effect, shrinks in the circumference of the main mirror, bringing it closer to the reflection of the diagonal and making it much easier to see the effects of small movements of the adjusters. The narrow ring of light seen when this mask is in use should be brought to an even width all round; when this has been done, the reflected focal cone has been centred on the diagonal as precisely as is possible in daylight. As the diagonal mirror is taken as forming one point on the axis, the other being the centre of the main mirror, it is necessary for the diagonal to occupy the axis of the telescope-tube. If not, the optics of the telescope will not be affected, but it may mean that with a narrow tube the full aperture will not be brought into use. This means, too, that the tube should be at least 2 inches greater in diameter than the aperture of the main mirror.

When all this has been done the effect as seen from the eye-tube should be perfectly concentric. Actually, it will certainly be the case that the reflection of the main mirror is slightly out of centre in the outline of the flat, displaced downward, but this effect is perceptible only when the main mirror is shorter than about f/6, and it is a difficult matter to avoid it by means of adjustments carried out in the daytime. The final refinements on an actual star image puts the apex of the cone from the main mirror precisely on the axis, and so these final adjustments cannot be omitted.

Preliminary adjustments with a refractor may be carried out by back surface reflection. Here the cap of the object-glass is left on, and the eyepiece removed. A brightly polished ring (a curtain ring,

for instance, or a wedding ring!) is mounted an inch or so clear of the eye-tube, and illuminated from the side. Looking through the ring into the darkened telescope tube, the reflection of the ring will be visible on the back surface of the object-glass, and should be brought central by tilting the object-glass. Secondary reflections of the ring may be visible, and serve as a refinement to the adjustment. Again, the final squaring-on demands an actual star image.

These adjustments having been completed, the peak performance of the telescope should be available. The remaining hazards are mainly outside the image-forming part of the instrument, and operate by deforming the light-beam either before or after it enters the sphere of influence of the objective (or mirror).

The offender in the first case is the Earth's atmosphere, and obviously there is not much to be done about disturbances occurring at a distance along the line of sight. Uneven refraction, caused by streams of air of differing temperature and therefore of differing density, plays havoc with the incoming beam. When the eye is placed at the empty eye-tube, and the illuminated objective surveyed, these refraction effects will be seen as patterns of light and shade; sometimes a mere turmoil, sometimes streaks of the 'garden-fence' type, and always in motion. It is not the motion that does the damage. It can, however, tell us a good deal about just where the disturbed air is, as slower movements nearly always mean greater distance.

Long-period disturbances in the atmosphere are quite beyond our control. Faster-moving air-streams and turbulence are, however, often much closer home, and may even be coming from the observer's person, since bodily warmth is quite appreciable. The remedy is obvious, as also is that for the internal turbulence that occurs in a closed reflector-tube which is open at one end, especially if the tube is made of unlined sheet-metal. As mere movement of the air is not the destructive factor, an electric fan applied so as to sweep out the offending 'muddle' of air of varying density will improve matters considerably. Some of the air-blast should be allowed to play across the actual mirror face, as a layer of 'sticky'

air seems to adhere to it, moving almost as a viscous liquid and producing slow, languid changes in the image quality. If the air from the fan can be arranged so as to sweep across the mirror from several points on its circumference, and to meet in the middle, proceeding thence upward out of the tube mouth, everything should be well. Some people prefer to do it the other way round, pulling air in from the tube mouth and venting it from the bottom, but here it is not easy to arrange for the actual mirror face to be scavenged by the air-blast – and this is a distinct drawback, since the mirror surface layer does spoil the performance quite noticeably on occasions, and may thus be regarded as a fault capable of being remedied.

Most 'direct' faults, arising from primary errors, have now been considered. As anything which leads to less than optimum performance may be described as a fault, however, it is permissible to examine here some common forms of construction leading to reduced performance, and to say something about the methods of avoiding or rectifying them.

The first that springs to mind is the plain cylindrical sheet-metal tube of the average reflector. It must be admitted that sheet-metal is the most suitable constructional material, being inherently rigid longitudinally, capable of carrying the loading stresses unavoidably applied by the weight of the mirror, and itself, with the minimum of deflection (a point not usually considered by telescope makers). It is also very easily worked. On every other count it is one of the most unsuitable materials imaginable, being an excellent conductor of heat and thereby being a prime cause of tube currents. With a sheet-metal tube, indeed, currents are inevitable, since the upper end of the tube is always in a colder layer of air than the lower end; it is higher, and the upper side of the tube is free to lose heat by radiation to the sky, while the underside is less free to do so in view of its proximity to the (comparatively) warmer ground. Moreover, the observer's side of the tube is close to the observer himself, and bodily heat is not to be neglected. It follows that a tube starting an observation session with a content of still air will not remain in this happy state for long, and will soon need

a blast of air from a fan to clear it. Yet prevention is better than cure, and some sort of lining to keep the air in the tube from contact with the walls is the logical move. There is nothing new in this, of course. Members of the British Astronomical Association have been doing it for years (together with most other telescopic 'dodges'!), and its *Journal* contains many notes on the subject.

Anything that is a non-conductor and will stay put inside the tube will do as a lining, so long as it does not shed fibres on to the mirror. Sheet cork is expensive, but has been used; I have used fibre board – hence the warning about loose fibres – and my present 24-inch reflector has all its internal metal surfaces, apart from the secondary support blades, covered with two layers of Sizalkraft bitumized paper. Foamed plastic sheeting about a quarter of an inch thick is now obtainable, and ought to do the job well; it is inexpensive, and is easily fitted.

In my own case, I have been forced to adopt a sheet-metal tube, lined and blown, since the telescope is exposed to the weather all the time, and in this situation the alternative types have serious drawbacks. Over the years, with the various telescopes I have had, I have fought these drawbacks, with the result that some of them at least have been eliminated from the present 24-inch, though there is still room for improvement in the means used to support and focus the secondary mirrors of the Cassegrain and Gregorian systems.

The off-axis reflector was described by Herschel, who simply tilted a long-focus, nominally spherical mirror until its focus cleared the incoming beam. The theoretically more correct off-axis paraboloid followed, and was being made in the late nineteenth century by at least one expert. Only this type of reflector avoids the need for an obstruction in the incoming beam of light. All others use some form of secondary mirror in order to make the focal plane approachable, and this secondary mirror needs to be supported accurately and precisely in the axis of the main mirror, which generally means somewhere near the centre of the tube. The supports should obstruct a minimum of the incoming light,

and should be capable of carrying the secondary mirror and its adjusting devices without sensible deflection.

It is simple to fix a secondary by using metal blades under tension. These, by being set edgewise, cause practically no loss of light. The simplest form of all uses only one such blade, and cannot be tensioned, but naturally this single blade must be thicker, in order to provide any rigidity at all. This 'single-arm support' is found mainly in older instruments of small aperture; with larger telescopes, it tends to shift about.

The next form uses three blades at 120 degrees, under tension. It is as satisfactory as any in its mechanical features, and it, together with its four-bladed equivalent, is the most common type. As usually made, the blades terminate in tension screws, passing through slots in the tube walls. The slots restrict movement along the axis; the tube wall has to be strengthened to resist the tension needed to stiffen the whole arrangement, though even then the necessary tension is seldom attained. If, however, these tension supports have their blades fitted to a steel ring sliding inside the tube, all hazards are removed; the fitting becomes utterly rigid in all planes, and adjustable longitudinally, without perforating the tube walls. The stresses acting on a secondary cause deflection toward the ground, and thus tend to de-centre the secondary, making it move off the optical axis. As the telescope takes up its various positions, the angle and extent of the deflection change. This 'nodding' of the secondary may be countered by making the blades of a tapering outline, and using considerable tension on them. The main part of the stress, however, is the straight-line gravitational sag or nod, and the steel-ring arrangement is the best solution.

There is one form of four-bladed support system that dispenses with any tension. Here the blades are not radial, but contact the hub at two opposite points (Fig. 1). Study of this arrangement will show that the hub is extremely rigid with regard to rotational stresses, as it cannot rotate at all without stretching one or other of the blades. Unfortunately there are no rotational stresses at all acting on a secondary, while sag or nod deflections are always

present. In this design some strength in the line of the blades may be obtained by making them of considerable width; but as these blades support the hub at each end of its diameter, it is only this diameter that makes any pretence of being sag-resistant, the diameter at right-angles to it merely having to flex the blades slightly. The strength, where it matters, of this type of secondary support is much less than with other types, and moreover the strength is distributed asymmetrically. It would seem that its one virtue, i.e. lack of necessary tension, is dearly purchased, and I have therefore included it here as an 'avoidable instrumental fault'.

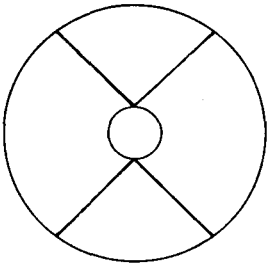


Fig. 1

All secondary supports cause trouble with the optical image, giving rise to streaks of light apparently emanating from it. These 'diffraction rays' are related to the number of blades used in the support. Thus, a single-arm support will produce a single streak across the star image, but, while the single arm is radial, the streak or diffraction ray is centred on the image and extends on both sides of it. We could have the secondary carried by one diametrical blade – or, to put it another way, two opposite radial blades – without producing more than one diffraction ray.

The next in the series is the three-blade support. This produces six diffraction rays, and 'messes up' the field in the immediate vicinity of a star. The last in the series, with four blades, produces four diffraction rays, and this irrespective of the four blades being radial or of the off-set arrangement described above. As the diffraction rays must pass through the image, and be centred on it,

the precise positioning of the blades causing the rays does not affect the diffraction pattern.

It would seem that all secondary support arrangements must, to some extent, be defined as faults, even though unavoidable ones. We have, therefore, the single-arm, defective on the mechanical side as being hard to make sufficiently stable, but offering the most favourable diffraction pattern; the three-armed support, simple to make rigid but with the most numerous diffraction rays of all; and the four-bladed support, slightly more intricate than the three-bladed type and yet with fewer diffraction rays. On balance, the radial, four-bladed support emerges as the best solution.

The presence of these diffraction rays is embarrassing when observing double stars. One or other of the rays invariably seems to occupy the position-angle of the fainter component of the double. Also, as even an extended object consists, in the last analysis, of point images, diffraction effects are bound to reduce the contrast. Therefore, any method of reducing the diffraction rays must lead to a telescope which is less 'faulty'.

Diffraction effects stemming from the obstruction of the beam by the secondary itself are also present, but are negligible if everything is properly adjusted. Rays originating from the support blades may be removed by giving the blades a curved profile instead of the usual straight line. Quite a lot of work has been done on this subject, and the clearance of the field when curved masks are clipped on to the blades is quite dramatic. The inevitable result of breaking the thin, straight obstruction of the blade edge into an obstruction with curved edges by means of masks, while dealing with the rays, unfortuntely results in loss of light, which may also be classed as a fault. It occurred to me that all these points relating to rigidity, tension on blades, diffraction effects stemming from them, etc., could be at least improved by altering the initial design. My own telescopes, including my present 24-inch, have had cubical lower sections, carrying a cylinder forming the front, upper three-quarters of the length. This enables the weight and rigidity of the tube to be graduated according to the

stresses acting on each part, by building the cube massively and the cylinder lightly. I have reached the conclusion that further improvements can be made by changing the cylinder to a D-shaped section or, more simply, a square one. Such a D-section has been built into the cylindrical part of the tube of the 24-inch in order to provide room for certain accessories, but the square would be easier to construct and brace; and as it already exists in the lower third of these tubes, a case can be made for using it throughout. Should a square-section tube be adopted, its 90-degree internal angles provide a register throughout the whole length, which may be utilized to locate and carry a secondary support that does not give rise to concentrated diffraction rays, while possessing satisfactory (not ultimate) rigidity without blade tension. This device is simply a short piece of metal tube of suitable diameter to enable it to nestle down in the internal angle of the telescope-tube, while passing behind the central area obscured by the secondary mirror which is mounted on it by the usual tilting screws (Fig. 2). The

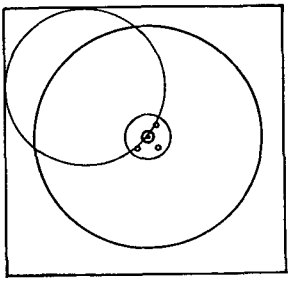


Fig. 2

secondary is thus supported in the main tube axis by two thin curved blades which obscure a minimum of the incoming light, are virtually self-supporting by being part of a cylinder, and which, because of their curved section, do not give rise to stellar diffraction rays. The tube forming the support need possess only one square end, and one long side (that which fits into the angle). The remainder is best cut away on the slant, in order to reduce passenger weight and, more important, to reduce the mass of

heat-radiating or heat-absorbing metal present in the beam. It would therefore present a side elevation as shown in Fig. 3. For telescopes using various optical systems, such as Newtonian, Cassegrain and Gregorian, each with its own support, this method

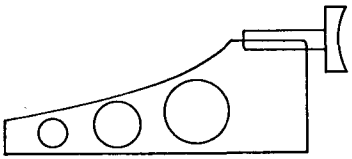


Fig. 3

of construction makes it simple to provide a support for each system as well as to position it accurately. If the internal angle of the main tube is straight, and all the supports are identical, then the supports will also be co-axial. Removal of a secondary from the optical system in order to permit the use of any of the alternative arrangements may be effected by a 90-degree rotation of the support tube, which will move the secondary out of the beam. Simple contact stops will permit accurate replacement in the previous position when changing back to the original system. This type of secondary support offers a simple means of focusing (essential for Cassegrain and Gregorian telescopes, in which eye-piece focusing is impracticable) by sliding the whole unit along the angle via a long screw. It therefore resembles the old single-arm sliding mount, but is simpler to construct and is much more rigid. At least one telescope with this curved-blade secondary support is in use; it is a 17½-inch instrument. The star disks have been found to be greatly improved by the absence of diffraction rays.

Introduction to Mars

PATRICK MOORE

Mars will be a brilliant object in the night sky during the first part of 1965. It reaches opposition on March 9, though it will actually be at its closest to the Earth on March 12; its magnitude will then be $-1{\cdot}1$, so that it will shine almost as brilliantly as Sirius and will far surpass any other star. At opposition it will be in Leo, roughly between the naked-eye stars Beta Leonis (Denebola) and Chi Leonis.

This being so, it will certainly attract much attention from amateur as well as professional observers; and it will be rather surprising if a new rocket has not been launched toward it. (The first Mars Probe, sent up by the Russians in 1962, was something of a disappointment, since radio contact with it was lost long before the vehicle had arrived anywhere near the Martian orbit.) In the *Yearbook* for 1963, G. de Vaucouleurs, the French astronomer who has written the standard book about Mars, described some recent research; in the present *Yearbook* we have an article from S. Miyamoto, of the Kwasan Observatory in Japan, dealing specifically with the clouds observed in the Martian atmosphere. To appreciate Professor Miyamoto's article to the full, some background information is needed, so that a brief 'introduction to Mars' may not be without its use here.

Mars is a smaller planet than the Earth. Its diameter is 4,200 miles, and its mass only 0·11 that of our world, so that the surface gravity is only 0·38 of the Earth's. Escape velocity is 3·1 miles per second, so that the atmosphere may be expected to be thin – as indeed it is. The mean distance of Mars from the Sun is 141,500,000 miles, but the orbit is appreciably eccentric, so that the distance ranges between 128,500,000 miles at perihelion and 154,500,000

miles at aphelion. This eccentricity causes the various oppositions to be unequal. When opposition occurs at Martian perihelion, the distance from Earth may be reduced to about 34,000,000 miles; in 1965, unfortunately, Mars is near aphelion at the time of opposition, so that it will never come within 60 million miles of us. The next really close oppositions will be those of 1969 and 1971, though Mars will then be well south of the celestial equator.

Moreover, since Mars is a comparatively small world, it is by no means so easy to 'observe' as might be thought. De Vaucouleurs has justly pointed out that even our largest telescopes will show Mars no better than a pair of binoculars will show the Moon, and it is natural that fine details should escape us. At aphelic oppositions, such as that of 1965, very little useful work is possible with modest telescopes. Something may be done with, say, an 8-inch reflector, but at least 12 inches is needed for serious research, and even this is on the small side. Of course, the main details, such as the Syrtis Major, are readily detectable with a 6-inch or even less, but the minor features will be lost. During March the apparent diameter of Mars will attain 14 seconds of arc, but this is less than one-third of the apparent equatorial diameter of Jupiter.

The north pole of the planet will be turned towards the Earth, and the polar cap should be relatively prominent. Nowadays, there is little doubt as to the nature of the polar caps; they are made up of some icy or frosty deposit, as G. P. Kuiper showed by his spectrographic investigations of more than 15 years ago. On the other hand, they are not much like the deep snow-caps of our own poles, since they cannot be more than a few inches deep at best. It has even been suggested that they represent nothing more than a surface coating of hoar-frost. When they shrink, in the Martian spring and summer, they may either evaporate in the conventional manner or else sublime, i.e. change directly from the solid to the gaseous state. It seems probable that sublimation must play at least an important rôle, though different authorities hold different opinions.

In any case, the amount of water-vapour in the atmosphere is

very small; it was only in 1963 that the first proof was obtained that water-vapour existed at all. The composition of the atmosphere itself is still a matter for debate, but according to de Vaucouleurs it is made up mainly of nitrogen, with smaller amounts of carbon dioxide, argon and (probably) oxygen. Oxygen is undoubtedly scarce, and cannot make up more than 1 per cent of the atmosphere. Earth-type creatures, then, could not breathe on Mars.

Since Mars is farther from the Sun than we are, it must presumably be colder, and this is borne out by direct measurements as well as by theoretical investigations. On the equator, at noon in summer, the temperature may rise to over 70°F., but the night temperature must drop to at least —100°. The thin, dry atmosphere is very poor at retaining heat, and so there are great diurnal extremes of temperature.

The best that may be said is that from all indications the Martian atmosphere is not likely to be toxic. The American astronomers C. C. Kiess, S. Karrer and H. K. Kiess have put forward an alternative view according to which there are poisonous oxides of nitrogen, but there seem to be serious objections to this idea, and not many astronomers support it – even though it cannot be definitely ruled out.

Clouds are common enough, but will not be discussed here, since they are dealt with by Professor Miyamoto. Meanwhile, mention must be made of the so-called 'Violet Layer', which seems to be strangely opaque to radiations of short wavelength. Its nature is obscure, and it is not directly visible, but it is certainly significant, and it may well afford good protection against various undesirable radiations coming from space. Note, too, that the Martian atmosphere is fully adequate as a meteor-screen.

The dark areas have been well mapped, and are virtually permanent, though minor alterations in form and extent take place. The most conspicuous of them is the rather V-shaped Syrtis Major, once known as the Hour-glass Sea, which lies mainly in the southern hemisphere; closer to the south pole lie the well-marked bright region of Hellas and the celebrated dark streak of

the Hellespontus, mentioned in Professor Miyamoto's article. Extending from the Syrtis Major are various other dark areas, notably the Sinus Sabæus and the Maria Tyrrhenum and Cimmerium. These features will not be best placed in 1965, but the opposition will give a good opportunity for studying the chief marking in the northern hemisphere, the wedge-shaped Mare Acidalium, which is generally prominent when the north pole of Mars is turned toward the Earth.

The Martian dark areas have given rise to interminable arguments. They have been attributed to moisture-gathering salts, to dust, and even to volcanic ash. However, it is now usually thought that they are due to living organisms of some kind, presumably of lowly type. We hear a great deal about 'lichens' and 'mosses' on Mars, but it is dangerous to jump to conclusions. The organisms, if they really exist, may be quite unlike anything found on Earth; all we can say, with some degree of confidence, is that they are not likely to be more advanced in type than terrestrial lichens or mosses.

Much of Mars is of reddish-ochre colour. These areas have been named 'deserts', and the name is not inappropriate so long as it is borne in mind that there is no real analogy with our Sahara or Desert of Gobi. The ochre plains are thought to be coated with reddish mineral, perhaps felsite or limonite; sand is certainly absent. Moreover, the temperatures are very low, and the deserts are appreciably cooler than the adjacent dark regions.

Mars has always been regarded as the planet most likely to harbour life. Now that America's Mariner II has shown Venus to be hopelessly hostile, it is indeed true that Mars is the most promising member of the Solar System – and, as we have seen, there is every reason to think that living organisms do exist there. Yet conditions are unfavourable for the existence of higher forms of life. Following a suggestion of mine, F. L. Jackson, in London, has carried out some experiments with containers simulating Martian conditions, and has demonstrated that some terrestrial bacteria are able to survive in such an environment; but more advanced life-forms are totally unable to do so. We cannot, of

course, discount the possibility of entirely alien creatures which are perfectly comfortable on Mars, but all the weight of scientific evidence is against it.

The famous canals, first reported in detail by G. V. Schiaparelli in 1877, have caused endless controversy. Whatever they may be, it is a fact that drawings of them made with small telescopes, showing Mars covered with an intricate network, cannot be trusted. There is an easy way to show what is meant. If you make such a drawing, and firmly believe that you have seen the canal system with (say) a 3-inch refractor or a 6-inch reflector, take your sketch and then work out the minimum breadth of a canal which would be detectable under perfect conditions – making allowance for the fact that a linear feature is easier to see than a small spot. Then broaden your canals until they have reached the minimum width truly visible. You will almost certainly find that you have shaded in the whole planet!

This is not to say that the canals are completely non-existent; that they are present, in some form or other, seems highly likely. For instance, G. A. Hole, with his fine 24-inch reflector, drew several during the opposition of 1962–3. But they are probably made up of disconnected spots and streaks which give the impression of forming a hard, sharp track, and few people now agree with Percival Lowell, who observed Mars studiously up to his death in 1916, and who firmly believed that the canals were artificial waterways, constructed by the Martians to form a planet-wide irrigation system.

I have observed Mars, sometimes under good conditions with large telescopes, at several oppositions – notably 1956, 1958, 1961 and 1963 – and I admit that I have never seen anything in the nature of a Lowell-type canal. Unconscious bias, however, is very hard to eliminate. I do not believe in Lowell-type canals, and I doubt whether I should see them even if they were staring me in the face, despite all my attempts to keep an open mind on the subject.

Finally, there are the two dwarf moons, Phobos and Deimos. Both are extremely small, perhaps 10 and 5 miles in diameter

respectively, and so both are faint. With Mars relatively remote, as will be the case in 1965, large telescopes will be needed to see the satellites, and the average amateur cannot hope to record them.

In every respect Mars is an intriguing world. Unwelcoming though it may be, it is not sterile – which is more than can be said of any other planet in the Solar System apart from the Earth. Unmanned rockets will be expected to land there well before the end of the twentieth century, and if progress is maintained there is no real reason to doubt that men will follow before the end of the twenty-first, but we have to confess that at present our knowledge of the Martian world is very far from complete.

Clouds in the Atmosphere of Mars

S. MIYAMOTO
(University of Kyoto; Kwasan Observatory)

Our knowledge of the Martian atmosphere has accumulated to an extent which makes it possible for us to be sure of the fundamental characteristics. The ground atmospheric pressure, obtained by polarimetic methods as well as albedo observations, is about 90 millibars. The pressure gradient is not known with any certainty, but is unlikely to be far from the adiabatic value in the lower atmosphere. Infra-red spectroscopy reveals a considerable amount of carbon dioxide – as much as 2 per cent by volume. Water-vapour is an insignificant component, and molecular oxygen has not been detected at all. Although there is no precise proof, there are good reasons for believing that the principal component of the Martian atmosphere is nitrogen, as for the atmosphere of Earth. This idea is supported by temperature measures; the sub-solar point reaches some 30°C., with the amplitude of diurnal variation attaining about 100°C. This wide variation is certainly due to the ineffective 'greenhouse' properties of the atmosphere.

With this information, we are able to proceed to the study of the dynamical and meteorological aspects of the Martian atmosphere. More than 40 years ago, M. Milankovic made theoretical investigations with regard to the surface and atmospheric temperatures. Following Milankovic's pioneer work, S. L. Hess applied the principles of meteorology to Mars, and in 1950 developed a general theory to explain the various meteorological phenomena on Mars. He gave the height of the Martian tropopause as 45 kilometres; adopting this figure, together with a pressure of 80 mb., a mean ground temperature of 273°K., and a dry adiabatic lapse-rate of 3·7°C./km., we obtain a temperature

of −170°C. and a pressure of 2 mb. for the tropopause. Using the temperature distribution in the southern hemisphere, in Martian summer, observed by Coblentz and Lampland in 1926, and obtaining eighteen cloud-drift observations to establish the wind directions, Hess was able to construct the first 'weather map' for Mars. He also estimated thermal wind velocities, which were somewhat lower than the corresponding values on Earth. Hess also pointed out the resemblance between Martian and terrestrial weather charts; each had a sub-tropical high-pressure belt, breaking up into high and low cells. However, he also noticed important differences between the general atmospheric circulations of Mars and Earth. According to him, the Martian atmosphere is extremely dry and free from cloud, so that the circulation pattern is quite regular. Moreover, the longer seasons on Mars give rise to exchanges of air masses between the two hemispheres.

Recently, G. Ohring has investigated the problem of radiative transfer in the Martian atmosphere, which obviously plays a more important rôle than it does on Earth. Ohring took into account the following absorptions in the long-wave region: 15μ band (CO_2); 6·3μ band with rotation band longer than 25μ (H_2O), and 9·6μ band (O_3). He calculated that the 'greenhouse effect' raises the average temperature by 14°C., and also discussed the average vertical distribution of temperature. He finally concluded that the adiabatic temperature condition (that is to say, the troposphere) extended up to about 9 km., and that in the stratosphere above, the temperature continued to decrease.

At the 1956 opposition of Mars, A. G. Wilson proposed a systematic international programme of observation of the Martian clouds. Previously, most observers had been concerned mainly with the seasonal changes of surface features – for which purpose it was sufficient to keep watch on Mars for a month or so around the time of each opposition. To record cloud drifts, however, to say nothing of the morning and evening mist, it is desirable to keep a continuous record throughout the night, extending the observation period as much as possible. Visual observation is the most effective means of detecting fine details of cloud distribution, and

observations must be attempted even under relatively poor conditions.

Martian clouds are often semi-transparent, and are noticed only because they produce a change in the background colour and brightness. Blue filters are helpful, both visually and photographically, when tracking down such clouds. It must be noted at once, however, that since the rotation period of Mars is only 37 minutes longer than that of the Earth, no single observer can cover the entire globe, so that international co-operation is essential if the records are to be complete.

Martian clouds are not infrequent. During winter the hemisphere concerned is almost always mist-covered; in spring, and again in autumn, a faint white cloud belt may be observed along the equator, possibly corresponding to our doldrums. This cloud belt is often strengthened at the morning or evening terminator, and is by no means hard to detect.

The development of morning and evening mist is affected by the topography of the area concerned. For example, morning mist over the southern part of the Syrtis Major is well known, while the Æolis, Elysium and Cerberus regions are often covered with heavy mist in the evening. The cloudiest season is the late spring of each hemisphere. In spring, with the advance of the season, the polar cap begins to shrink; moistened air masses move toward the equator, and are warmed by long-wave absorption from the surface, so becoming unstable. Thus the cloudy season develops with a certain 'phase lag' after the time of maximum shrinkage of the polar cap.

The most spectacular of the clouds, apparently seen at a definite date in every Martian year, is the yellow cloud over the Neith-Casius region in the northern hemisphere. At an areocentric longitude of the sun of 20 degrees, a brilliant white cloud appears over this region, subsequently developing into an extensive yellow cloud. The great yellow cloud observed during the 1956 opposition may be the southern equivalent of the Neith-Casius cloud.

Under normal conditions, the Martian atmosphere is extremely dry; the average water-vapour content measured in precipitable

water is estimated to be of the order of 0·03 mm. Therefore, the planet's atmosphere is almost transparent to long-wave radiation. The carbon dioxide absorbs long waves, but this is limited to a narrow region in the spectrum, so that the air remains cold even when the Martian surface is comparatively hot; according to calculations by Milankovic, the atmospheric temperature just above the ground is about 35°C. lower than the surface temperature.

Since it is transparent to long-wave radiations, the atmosphere of Mars is usually inactive and stable. Only when moisture is supplied, at the time of the shrinking of the polar cap, does the rôle of water-vapour become significant. However, unusual phenomena are often recorded; during the 1963 apparition, for instance, the behaviour of the polar cap was somewhat anomalous. It stopped shrinking for a while, and even increased slightly, while two 'cloudy' periods were observed instead of the usual one.

The Neith-Casius cloud, described above, provides another example. My interpretation is as follows: on Mars, moistened air over the evaporating polar cap pours out along definite courses. In the northern hemisphere, the Casius region lies on the vapour course marked by Utopia, Nodus, Laocoöntis and Gomer. As the moist air proceeds to lower latitudes, it is heated up by the absorption of long-wave radiation from the warm ground, so that, subsequently, a strong ascending current is induced. This first appears as a white cloud, while in later stages of the development it turns into a yellow cloud tarnished by the fine material (dust) from the desert.

The Neith-Casius cloud is one of the most spectacular phenomena of the Martian atmosphere, and may be compared with our typhoons and tornadoes. However, there is no sign of a vortex pattern, which is so characteristic of terrestrial cyclones. In the dry atmosphere of Mars the energy supply is severely limited, so that any ascending current is unable to develop into a major cyclone. In fact, there may be a marked distribution of cyclones and anticyclones, as on Earth, though the pressure difference as

estimated from the velocities of the drifting clouds is only about 2 millibars.

Through our telescopes, we are able to obtain an overall view of Mars; the global distribution of the cloud is observable at a glance, and the study of the general atmospheric circulation is a fascinating one. It is only recently that meteorological satellites (the Tiros vehicles) have enabled us to make a start in the same types of observations for our own planet.

Despite the similarity of the axial inclination and the rotation period for Earth and Mars, the circulation patterns are not the same. This is demonstrated observationally by the 'migration' of the polar coating between the two hemispheres. The moisture is carried from pole to pole, and this means that there must be a strong current across the equator, which is not the case in the troposphere of the Earth.

The cross-equatorial current may also be confirmed theoretically by preparing the 'radiation budget' for each belt of latitude. In the Earth's equatorial zone, insolation exceeds long-wave radiation, while in the polar region the converse is true; this means that the air-current is carrying energy from the equator to the pole. For Mars, information about ground temperatures may be obtained from radiometric observations, and the amount of insolation is easily calculable. The result is that we find an energy excess over the equator, and negative excess over the pole; near the summer solstice, however, the pole shows a positive excess, and there is a large negative excess throughout the winter in the hemisphere concerned, indicating that energy is being carried from the pole to the opposite hemisphere across the equator.

The excess energy over the pole in summer is due to the transparency of the Martian atmosphere. In summer, the 'midnight sun' warms up the polar region directly, without weakening by atmospheric absorption. The same is true for Earth, if we calculate insolation outside the atmosphere; the pole receives the greatest energy in summer.

The inverse direction of energy-flow may be detected observationally by the reversal of the prevailing wind. In Martian summer

the prevailing wind over middle latitude is easterly. The great yellow cloud of the 1956 opposition and the Tempe-Arcadia-Propontis cloud of the 1963 opposition were both blown by these easterly winds, in accord with theoretical prediction. The former appeared in the southern summer, the latter in the northern summer.

Y. Mintz has shown that the amount of energy excess on Mars is not great enough to give rise to a circulation of lateral mixing, as on Earth. According to Mintz, high and low pressure cells will not develop on Mars, and jet-streams are very weak at best. The mixing of warm and cold air-masses is produced by ordinary longitudinal circulation. The observed distribution of cyclones and anticyclones over Mars may be of thermal origin, and affected by local topography; the general circulation may therefore be determined by local thermal circulations.

At present, we are far from understanding the nature of the general atmospheric circulation on Mars, but a tentative picture may be given. In winter, the polar cap reaches its greatest extent. In the early spring it begins to evaporate, and water-vapour is released into the atmosphere. This vapour is carried from the winter hemisphere to the opposite side of the planet, across the equator, by air-currents, through definite vapour courses. The driving agent of the air-current is, then, the increased moisture in the air. With the advance of spring, the circulation pattern changes, and the air-mass exchange takes place between the equator and the poles; this is the cloudiest season on Mars, and floating clouds are observed here and there almost every night. With the approach of midsummer the circulation pattern changes again; the air-mass exchange takes place between the cold and warmer hemispheres, and meanwhile moisture is deposited gradually over the cold polar region of the winter hemisphere. During this season the winter hemisphere is covered with mist, while over the summer hemisphere the sky is clear and free from cloud. In autumn the rôle of the two hemispheres is reversed, and the shrinking of the other polar cap begins.

Meteoritic Craters

HOWARD MILES

The possibility of man landing on the Moon within the next decade has made it essential to know in advance the surface conditions which he is likely to encounter as the rocket alights on its surface and also when he steps out of his spacecraft. Every technique known to astronomers is being used, but there are still very many questions which remain unanswered. The solution to the old question of whether the lunar craters have a volcanic, meteoritic or some other origin may be near at hand, but at the moment there are still very wide differences of opinion amongst lunar observers. Most are agreed that some of the craters have meteoritic origins, the main controversy being centred on the actual percentage.

Obviously, if meteoritic craters exist on the Moon, they should also exist on the Earth. Because the Moon lacks an atmosphere, erosion due to wind and rain is non-existent, and the crater will remain substantially unaltered for millions of years. Any such crater formed on the Earth will weather rapidly (geologically speaking) and therefore those which can be identified now will have been formed fairly recently, most of them in the last geological era. Because less than half the Earth's surface is covered by land masses, it is not expected to find vast numbers. Nevertheless, the number of craters known to have been formed by meteoritic bombardment is much higher than most people imagine. Since the last war aerial photography has been carried out extensively in certain areas, notably in North America and Australia. In these areas, many craters of suspected meteoritic origin have been found.

The problems of identification are complicated by the fact that

geological processes such as volcanic outbreaks and subsidence will give craters which appear similar to those formed when a massive meteor hits the Earth. If the area under investigation is free from volcanic activity, and if the underlying rock strata are undisturbed, the two processes mentioned above can generally be excluded. Evidence of a violent explosion such as the shattering of the rock structure and of intense heat such as the production of silica-glass in a sandy location points to a meteoritic origin. The existence of meteorites in the immediate neighbourhood is, of course, the best evidence. A magnetic anomaly, that is to say, a distortion of the normal magnetic field in the area, is considered further evidence of a meteoritic origin. Evidence gleaned from the degree of erosion and any legends about the area will give an indication of the age of the formation. In many cases evidence is conflicting and it is in these cases that one has to be very careful before a definite identification is given.

Objects from outer space are continually encountering the Earth. During most nights one can see evidence of this in the form of shooting stars. These 'stars' are only small pieces of rock less than the size of a pea being burnt up by frictional heat as they plunge into the atmosphere at speeds of many miles per second. All bodies, whether natural or artificial, suffer from the re-entry problem.

If the particles are a little larger, they may not be completely burned away before they reach the Earth's surface. Examples of these meteorites as they are called can be seen in many of the world's museums. Some weigh only a fraction of an ounce, whilst others weigh many tons. For example, one found by Peary on his journey to the North Pole and now exhibited in the American Museum of Natural History, weighs 30 tons. The largest single meteorite found so far is the Hoba West meteorite, which still rests where it was found on a farm in South West Africa. It weighs about 60 tons, but if allowance is made for all the rust (called iron shale) that lies around, an initial figure of 100 tons would be nearer the mark. There is no evidence of a crater surrounding the object.

If the visitors from space are very large, they may under certain conditions explode on striking the Earth, forming a crater. These craters are not just holes made by the meteor hitting the ground. The tremendous amount of heat energy released when a body travelling at many miles per second is brought to rest in a fraction of a second is more than sufficient to vaporize part of the meteor and the surrounding rock and thus cause a violent explosion. Débris is flung over a large area, leaving a crater in the centre of the disturbed region.

The best-known crater, and the one that has been examined more thoroughly than any other, is the huge depression in the Arizona desert. It was discovered in 1886 by some shepherds who thought the meteoritic fragments lying around were pieces of silver. Some time later a prospector staked a claim for the area and sent samples for analysis. Eventually, Professor Konig, of the University of Pennsylvania, analysed a fragment and found it contained diamonds. This caused more interest than the crater.

The crater is a huge basin-shaped circular depression about ¾ mile in diameter. The outer slopes rise gently from the surrounding plain to a height of 160 feet and then drop precipitously nearly 600 feet to a flat bottom covering an area of over 300 acres. Surrounding the crater to a distance of 6 miles is a huge quantity of fragmentary material ranging in size from a very fine dust to boulders weighing 4,000 tons. Mixed with this were originally large quantities of meteoritic iron and iron shale. Whereas over 20 tons of iron have been collected from the surrounding area, only four small pieces have been found inside the crater.

Analysis of the iron showed economic percentages of valuable metals such as nickel and platinum. Several attempts were made to locate the main mass of the meteorite, so that extraction could take place on a large scale. The first attempt in 1903 was concentrated in the flat area in the centre of the crater, but was abandoned when the drills, having passed through over 600 feet of iron-stained disturbed rock, reached the undisturbed layers. Later attempts were concentrated near or on the rim, particularly in the southern part. The angle of the tilting of the rock layers in

the rim varies from about 5 degrees at the northern end and gradually increasing to nearly 90 degrees at the south. In fact, it is estimated that at the southern end a 2,000-feet section has been lifted bodily about 100 feet! It was concluded that the meteor approached from the north and came to rest under the southern part of the rim.

On one occasion a drill penetrated to a depth of 300 feet before it was lost; a horizontal shaft was dug through the crater wall to recover it, and during the operation two shale balls were found within the débris of the wall. This was important evidence to support the theory that the meteorite fell at the same time as the crater was formed. On recovering the drill, work recommenced and, at 1,000 feet iron-stained rock began to appear. At 1,200 feet the drill passed through powdered iron shale similar to the rusted meteorites found on the surrounding plain. At 1,300 feet the sludge was 50 per cent iron, but at 1,376 feet the drill became jammed on something hard and could not be moved. It was suggested at the time that this was the main mass of the meteorite, but now this is thought unlikely.

Evidence for a meteoritic origin is overwhelming. The undisturbed rock layers existing below the crater rule out the possibility of a volcanic or similar origin. The presence of iron and shale intermingled with the rock boulders indicate a common origin. Evidence of a very high temperature is shown by the presence of quantities of silica-glass. The existence of thousands of tons of shattered sandstone, called rock-flour, almost as fine as talc, indicates a violent explosion. Intermingled with the rock-flour are grains of sandstone which crumble into the fine rock-flour when a small pressure is applied.

A fairly recent origin is indicated by the fact that the rock-flour is used in the religious ceremonies of the Hopi Indians, who also say that three gods descended from heaven, one making his home in the crater and the other two some distance to the north. No other craters, however, have been found in the area. The crater could not have been formed less than 700 years ago, because of the age of trees growing on the rim: but because of the small

amount of erosion of the scattered blocks it could not have been formed more than 5,000 years ago.

An even larger, well-defined crater exists in Ungava, in northern Quebec Province. Although it was first noted by a U.S. weather plane in 1943 and again on an aerial photograph in 1948, the first expedition to the area did not take place until 1950. Because of its extreme northerly position, the only method of reaching the area is by amphibian aircraft and this can be used only for about one month in the year when the lakes are free of ice. It was during this period the following year that a full-scale expedition visited the area. They found a circular crater roughly three times the diameter of the one in Arizona. The general shape was similar, having gentle outer slopes and very steep inner ones, and boulders scattered all over the surrounding regions. Although most of the information obtained did not give strong evidence for a meteoritic origin, it definitely excluded other methods of formation.

The water in the crater lake was different from that in the surrounding lakes. It was so clear that a black and white disk could be seen at a depth of 115 feet, and that under not ideal weather conditions. The amount of plankton was exceptionally low, showing that the lake could not support abundant fish life. In fact, the few fish that were caught had abnormally thin bodies and large heads compared with similar types of fish caught in the neighbouring lakes.

It was unfortunate that the magnetometer survey had to be carried out during a period of frequent magnetic storms, but even so a magnetic anomaly was located just before the party left the area. The anomaly was located lying between the two highest points on the crater rim, which is slightly lopsided and rises roughly 600 feet above the surface of the lake. During a later expedition similar magnetic anomalies were noted at other points on the crater rim and have been attributed to the mineral magnetite which can be seen in the granite gneiss. No meteoritic material has been found, but this is to be expected because the whole of the surrounding area has suffered heavy erosion due to glaciation. There is no doubt in the minds of the investigators that the crater is of meteoritic origin.

Since the last war, extensive use has been made of aerial photography for mapping the Canadian Shield. This has resulted in the locating of many circular features. Some have definitely been shown to have non-meteoritic origins, but there are still quite a few which cannot be eliminated easily. In some cases erosion has nearly removed all evidence of a crater, the circular nature being evident only from the air.

The largest of these suspected meteoritic craters is Deep Bay in Saskatchewan. It has a diameter of $8\frac{1}{2}$ miles, and the rim rises on an average 270 feet above the water in the lake, itself $6\frac{1}{4}$ miles across. The bottom of the lake lies over 1,100 feet below the crater rim. The great age of the feature and the considerable erosion due to glaciation makes it unlikely that meteoritic evidence will be found in the area. There is, however, considerable evidence to show that the crater was formed by explosion.

A crater of very great age, reckoned in hundreds of millions of years, has been recognized at Holleford in Ontario. It is a circular depression $1\frac{1}{2}$ miles in diameter and about 100 feet deep. The crater is filled with sedimentary deposits to a depth of several hundreds of feet, and when corrected for erosion the crater would have been similar in shape to the those at Ungava and Arizona.

Other craters having a suspected meteoritic origin exist at Merewether in Labrador and at Brent, Ontario: it will not be surprising to find further examples when further areas are examined thoroughly.

Excluding the one in the Arizona desert, there are at least nine more locations in the U.S.A. where existing craters are thought to be of meteoritic origin. At Odessa, Texas, there exist five small craters, the largest 500 feet in diameter and now only 12 to 15 feet deep. Detailed study of the deposits in the crater has made it possible to identify material which fell back in when the crater was formed, rock-flour similar to that at Arizona and the post-meteor fill. In crater No. 2, 70 feet in diameter, many hundreds of meteorites have been found. They have also been found in the surrounding area. It is possible that this is a case of an impact crater more than one formed by an explosion. The presence of a

fossilized horse at a depth of 12–18 feet in the main crater has enabled geologists to estimate that the crater was formed about 1,000 years ago.

At Haviland, Kansas, many hundreds of pounds of meteorites have been found in what was regarded as an old buffalo wallow. The crater is elliptical, 36 feet by 55 feet; and before it was identified as a meteorite crater, several attempts were made to fill it in.

At the other sites meteorites have not yet been found, but in several cases the mineral coesite, a type of silica formed by very high temperatures has been identified. Coesite has only been identified in the vicinity of suspected meteoritic craters; the existence of this mineral is now accepted as reasonably conclusive evidence for a meteoritic origin.

Australia, another country in which extensive use has been made of aerial photography for map-making, has many features suspected to be of meteoritic origin, although three were known to exist before the last war. The first of these to be discovered lies near Henbury in Central Australia. After samples of meteoritic iron had been sent to Adelaide University for analysis, Alderman visited the area in 1931. He plotted thirteen craters in an area of about half a square mile and in the areas surrounding the craters found many hundreds of meteorites together with large quantities of iron shale and silica-glass. The largest crater is oval in shape, measuring 660 feet by 360 feet, its shape being explained by two large masses landing simultaneously and very close together. Crater No. 6 on Alderman's map is 240 feet in diameter, and is known as the water crater, for it holds water for some time after rain and is the only one containing mulga and acacia trees, some of which reach a height of 45 feet.

There are several mysteries connected with this group. On the west side of the main crater silica-glass is found only close to the rim, but on the east side it has been found in long narrow strips to a distance of 1 mile. Further, radiating outwards from some of the other craters are low ridges of sandstone which gives the impression of having withstood erosion better than the surrounding

rock, although it appears identical, both physically and chemically.

There has been considerable erosion, and consequently it is thought that the craters are very old – but they cannot be too old, because the aborigines in the area will not camp near the craters; they call the area 'chindu chinna waru chigi yabu', meaning 'sun walk fire devil rock'.

In Western Australia, near Hall's Creek, a very large basin-shaped depression was discovered during an aerial survey in 1947. Although a little more than two-thirds the size of the Arizona crater, it appears very similar to the latter when viewed from the ground at a distance of a few miles. The crater rim rises 100 feet above the level of the surrounding plain, and the floor of the crater lies 200 feet below the rim. The small amount of erosion indicates a fairly recent origin although the aborigines have no legends about the area.

Other confirmed craters exist at Boxhole in Central Australia and at Dalgaranga, Western Australia. The former is rather a shallow crater 600 feet in diameter, and resembles the main crater at Odessa, Texas.

In Arabia there exists another group of craters, which, although much smaller than the Arizona depression, is unrivalled for the information it gives us on the mechanics of the formation of meteoritic craters. They were found in 1932 by Philby, who was crossing the Rub'al Khali in search of the legendary city of Wabar, which was said to have been destroyed by fire from heaven. On reaching the traditional position of Wabar, Philby found two fine craters with evidence of two more lying under the sand. The essential features of the craters are identical with other meteoritic craters, but the rims consist mainly of silica-glass. For a distance of 130 feet from the rim of the main crater, the ground is covered with bombs of silica-glass and also small black pearls. The production of silica-glass on such a vast scale is obviously due to the meteorites' falling on clean desert sand. The bombs and the pearls are exceptionally light, the latter consisting of cellular white silica-glass covered by a thin coating of highly polished black glass. Under the microscope, the black glass is found to be covered with

numerous minute pimples. The physical structure of these bombs and pearls has been explained by assuming that at the time of the impact the intense heat vaporized some of the sand and meteorite to give an atmosphere of silica, iron and nickel, through which molten silica was ejected. The cellular structure is due no doubt to silica boiling and the black covering due to condensation of the vapour. The pimples were formed by dew drops of silica in the last stages. The silica-glass itself contains millions of minute spheres of nickel iron, suggesting a rain of molten metal falling into a pool of boiling silica. The highly polished surface of the black pearls indicates that atmospheric oxygen was completely excluded!

The only other craters on the Eurasian landmass where meteoritic material has been identified lie within the boundaries of the U.S.S.R. On an island named Kaali just off the coast of Estonia there exists another remarkable group of craters. The main one is occupied by a beautiful lake 200 feet in diameter. Reinvalt, one of the principal investigators of the craters, spent many years in the vicinity, but it was only towards the end of this period that he found meteoritic fragments; this was no doubt due to the fact that the soil in the area had been tilled for hundreds of years. There are six craters in the group, and from the reports published they show a remarkable resemblance to the group at Henbury. The dimensions are similar; both contain an elliptical crater and the crater rims are partly formed by upward-tilted strata. Both bear signs of high temperatures, with the presence of silica glass at Henbury and burnt dolomite at Kaali.

Twice recently Siberia has suffered an intense bombardment from objects coming from outer space. The first occurred on 1908 June 30, when what is now thought to have been a comet struck a sparsely populated area in Central Siberia. News travelled very slowly, and it was not until 1927 that Kulik, of the U.S.S.R. Academy of Science, located the area of the fall. He found that the trees had been blown down outwards over a radius of 40 miles, those within a radius of 10 miles of the centre having a charred appearance. About 200 craters were identified. There have

been several expeditions to the area recently, the last one being in 1962. Information collected during this visit has shown fairly conclusively that the visitor from space was a comet, and that it exploded in the atmosphere.

In 1930 Whipple in this country noticed a coincidence between the date of the fall and the date on which most unusual vibrations were noticed on the microbarograph, an instrument designed to record small rapid changes in atmospheric pressure. From these observations he was able to distinguish the air waves caused by the passage of the comet through the atmosphere and those caused by the explosion.

The other fall occurred on 1947 February 12 in Eastern Siberia. The meteorite, believed to have weighed several thousand tons, was seen to fall by inhabitants over a circle of 130 miles radius. It travelled north to south for about 4 to 5 seconds, the light from it being far more dazzling than that of the sun. In fact, observers said that all objects had two very strong shadows, one from the meteorite and the other from the sun, which was shining in a clear sky. The mass of the meteorite broke up in the sky, and over an area of 6 square miles there occurred a shower of iron rain. In an elliptical area of half a square mile, 100 craters have been located and over 10 tons of meteoritic fragments have been collected. The area was declared a forbidden zone for five years, and placed at the disposal of the Academy of Science for research.

Apart from two small well-defined craters at Murgab, in the Soviet Union, the rest of the features in the Eurasian land mass which are thought to be of meteoritic origin do not have impressive appearances, although some are extremely large in diameter. Iraq contains two, the one near Baghdad being over 600 feet across and one at Al Umchaimim being only a little smaller than the one in Quebec. The $2\frac{1}{2}$ miles diameter feature at Köfels, Austria, and the one at Steinheim, Germany ($1\frac{1}{2}$ miles across), are dwarfed by the one at Nordlinger Ries, Germany, which is about 15 miles in diameter! Here, the mineral coesite has been identified.

Even this is smaller than the one at Vredefort, South Africa, where a crater 25 miles across exists. Another large one, 6 miles

in diameter, occurs in Ghana. Known as Lake Bosumtwi, it seems to have had rather a spectacular history. From examination of the gravel deposits on the rim, it appears that the level of the water in the crater fell 210 feet in a catastrophic manner in the fairly recent past. For the last 100 years it has been rising at the rate of 1 foot per year. The crater rim rises to a height of 600 feet above the surrounding plain, and the depth of the crater from the lowest point on the rim is 1,150 feet, the same depth to solid rock as in the case of the Arizona crater. Although a meteoritic origin was suspected for a long time, it was not until the identification of coesite in the neighbourhood that his explanation was accepted generally.

Most of the other craters in the African continent occur in or near to the Sahara Desert, the largest being at Talemzame, Algeria, where a single crater just over 1 mile in diameter exists. The rock strata in the rims are upturned at angles of from 15 degrees to over 60 degrees, and the highest points on the rim are over 220 feet above the floor of the crater. The large amount of post-meteor fill and the degree of erosion indicates a crater of considerable age.

It is obvious that when more of the Earth's surface has been mapped in detail, many more circular features will be discovered, and of these some will certainly be of meteoritic origin. Several circular features of even vaster proportions than the one described can be seen on the map of the world. It is possible that some of these may be found to have been formed by a meteor of unusually large dimensions.

In the above we have discussed the results of meteorites which have fallen in the past. What about the future? It is estimated that about 500 meteorites fall on the Earth every year, but of course most of these are very small. It is certain that very large ones will continue to arrive now and again. When they will arrive is anyone's guess. One must not forget that at least two have hit the Earth during the twentieth century!

The Radio Sun

F. W. HYDE

As stars go, the Sun is of comparative insignificance, being one of the many millions in the Galaxy which are designated 'G' type stars; but to the people on Earth it is the most important in the sky. The Sun is also a variable source of radiation, and this peculiarity makes it of great significance to the radio astronomer.

A great deal is known about the Sun; it is a great power-house consuming itself in the production of radiations, in which changes are taking place under conditions it is impossible to reproduce on Earth. In different parts of the Sun different conditions prevail. The effect of electrons which cause radiations when they spiral round the lines of magnetic force under conditions where the gas is far more rarefied than can be achieved on Earth can be examined. It is our ability to detect the radio waves they emit that makes these studies possible.

The Sun which is visible as a bright disk is some 864,000 miles in diameter. The disk is called the photosphere, and has a well-defined edge, as there is a sharp change of temperature-level between that and the surrounding gas of the Sun's atmosphere. The surface temperature is some 6,000°K.

Near the centre of the Sun the temperatures are of the order of 15,000,000°K.; the density is so great that it is a hundred times that of water, yet under these enormous pressure conditions the Sun still remains a gas. These conditions are just those required for the production of atomic fusion.

About 50 per cent of the mass is made up of hydrogen, and of the remainder the larger proportion is helium. This enormous aerial reactor radiates energy by convection from its central core to the surface of the photosphere, and from there it escapes as

radiation in all parts of the spectrum. A result of these nuclear processes is that it consumes about 4 million tons of its mass each second. The energy from the central zone is conveyed by the radiative transfer of photons moving from atom to atom on their outward journey. A convection zone covers this radiating core, and extends to within a few thousand miles of the photosphere; from there the energy is carried by the upward action of the heated material through an extremely steep temperature-rise. Thermal conduction is negligible.

Surrounding the photosphere there is the chromosphere, extending outwards for a distance of some 12,000 miles. Being slightly pinkish in colour, the name 'colour sphere' or 'chromosphere' is appropriate. At the lower levels of this, some 600 miles deep, there is a layer called the 'reversing layer', and it is here that the atoms are said to be ionized; that is to say, they have lost one electron. Intense ultra-violet radiation is produced in this area, caused by the electrons jumping from one level to another in the ionized atom. When this radiation eventually reaches the upper atmosphere of the Earth it contributes to the production of the ionosphere.

The intense energy produced from the interior of the Sun is absorbed principally in the chromosphere. Throughout the chromosphere there appear to be three separate temperature levels; one rising to 10,000°K. another up to about 50,000°K. and then at the outermost layer a tremendous rise to nearly 1,000,000°K. at the commencement of the corona.

Huge geyser-like projections known as spicules are continually emerging up into the chromosphere from the surface of the Sun, pouring into the chromosphere protons that eventually escape into outer space.

The corona, which lies beyond the chromosphere, was only visible at the time of total eclipse until the advent of radio astronomy, except by the use of a special instrument called a 'coronoigraph' designed by the French astronomer, Lyot.

The radio corona extends to a distance many times the diameter of the Sun. Due to activity from inside the Sun itself and the

chromosphere, the corona varies continually, and it sends out vast streams in all directions, there being times when it is in greater activity than others. At the time of sunspot minimum it has been observed that the rays and plumes have their greatest extension round the equator of the Sun, while the rays are much shorter and more uniformly distributed at the time of sunspot maximum. There are always well-defined areas near the poles of the Sun which are clear. The streamers follow the lines of the Sun's magnetic field.

The sunspot cycle of activity is regular, and varies between 10 and 11·2 years. Dark spots often mark the surface of the Sun, which increase in number when the period of maximum activity is reached. These are often quite small and hardly visible, while on other occasions they are large in size and may be in chains as much as 100,000 miles long.

These sunspots are generally in a well-defined belt around the equator of the Sun, and are visible signs of the huge areas of turbulence within. At the time of minimum activity they may occur in regions well to the north and south of the equator. Striking effects are noticed when a number of spots coalesce, causing bright bands to appear; on these occasions there is usually considerable radiation in the radio part of the spectrum. Sunspots do not necessarily indicate a high level of radiation so far as the radio astronomer is concerned.

Flares, which are caused by turbulences in the chromosphere, are terrific outbursts of gas sometimes appearing above sunspots. They are thought to be produced by the intense magnetic fields in these regions. Under such conditions great spouts of gas can be ejected from the Sun, complete with their own magnetic fields, shooting out together with particles into interplanetary space. Occasionally they pour into our upper atmosphere and cause intense changes and modifications. On other occasions these flares extend to limited distance and then fall back to the surface.

Prominences appear over the surface of the Sun. These are vast clouds of hot and very tenuous gas attaining extremely high temperatures. The prominences seem to bear a relation to the sunspot cycle, as about 2 years before maximum they appear to

be larger and more numerous in the higher latitudes of the Sun.

A type of prominence called 'eruptive' gives rise to short-lived radio bursts; these begin at the high frequencies, and as they die away the radiation falls quickly to the lower frequency level. The process responsible for this seems to be the excitation of gas in the corona by disturbances caused by clouds of ionized material travelling outwards at high speed.

The emission of radio waves from the Sun can be detected at all times, but is subject to enormous range and variation of level. For many days the radiation may be at a nominal level, and then suddenly increase by many hundreds of times; these conditions are called 'noise storms'. The appearance of flares and prominences is usually followed by noise storms. Much of this activity is associated with sunspots. Before the formation of a sunspot a magnetic field develops rather like a large magnet below the surface of the Sun; when this giant magnet reaches the surface, the field sticks up through the photosphere and activates the gas in the chromosphere. The gas is heated by the hydro-magnetic waves, and travels up the magnetic lines of force. Spots then become visible; they are dark because the temperatures at these points are lower than the surrounding areas and mark the positions of the greater concentration of the magnetic field. Above the spots the gas is hotter and there is violent activity. Suspended high up in the corona are glowing clouds of gas supported by the magnetic field. It is during this time that flares may come into being.

The wave radiation can be divided into three parts. First is the ultra-violet light which falls upon the ionosphere, causing ionization of the 'D' layer. The second gives rise to variations in the magnetic field of the Earth, and causes fade-outs in radio communications between 5 megacycles and 20 megacycles; the third is an interference on the very low frequencies of 10 to 15 kilocycles. Radio waves at 60 megacycles give rise to great outbursts of radio noise. All these, together with visible light, arrive at the Earth some 8 minutes after the outburst has begun on the Sun. A later effect is that of cosmic rays created during the process and, consisting as they do of atomic nuclei, again causing ionization in our

upper atmosphere. This occurs some 20 to 40 hours later than the appearance of the flare, and at this time there are magnetic storms, ionospheric storms and under very severe conditions the appearance of the Aurora Polaris.

Wave radiations have simultaneous effects, but the delayed effects caused by the particles may go on for some days after the origin of the outbursts. This sequence of events is illustrated in Fig. 1.

Several types of bursts are recognized, and these are numbered. Type II and type III are similar, although the type II bursts are by

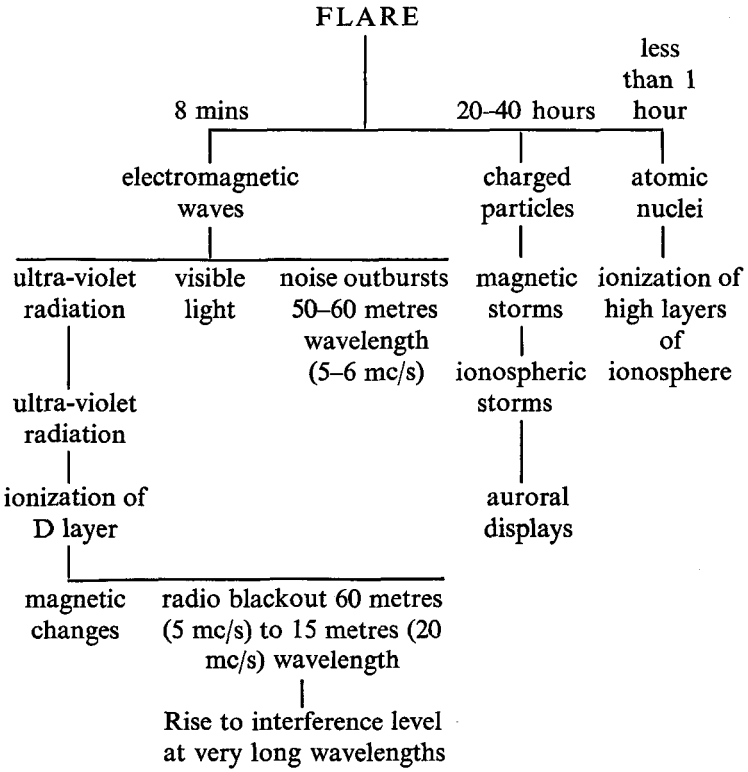


Fig. 1. Some of the effects of flares on the Sun

far the stronger. These are associated directly with the flare. Type I bursts do not follow closely after the activity caused by the flare. Near the sunspot maximum the flares increase in number, and may indeed occur at the rate of several in an hour. Some of these flares may last only a matter of seconds.

Type III bursts were first recognized in Sydney, Australia, and it was suggested that the frequency drift from a high to a low frequency was due to a disturbance travelling outwards through the solar atmosphere probably caused by a cloud of ions. It was established that the sources of type III bursts move with velocities approaching that of light. This is consistent with a 'resonance' hypothesis, but leaves the origin of the radiation unexplained. Spectacular radio bursts, that is to say the type II bursts, generally follow the emission of type III bursts. The frequency drift in the case of type II shows a much lower velocity, and therefore a slower change.

There is another type of burst, known as type IV, which has been studied intensively in France, and relates to frequencies in the region below a few hundred megacycles. The intensity of this radiation may be associated with type II bursts, but is characterized by a steady level, and in some cases may last several hours. The French observers have shown that this is generated in the high levels of the corona, where the temperature deduced from these radiations would appear to be of the order of 10,000,000,000°K.

As opposed to the very active Sun there is a condition of the quiet Sun. During this period most of the radiations are of thermal origin. The first observations of this solar radiation at a temperature of 10,000°K., corresponding to a wavelength of a few centimetres, was made with wartime radar equipment. A characteristic of this centimetre radiation is that it appears to increase at the edge of the visible disk of the Sun; after this, the level becomes more smooth as the wavelength increases. Below 1 centimetre the chromosphere only is seen, and moving outwards towards the corona the measurements at the longer wavelengths reveal that high temperatures exist. At a wavelength of 3·7 metres the temperature has risen to 1,000,000°K.

During the period of the quiet Sun many important observations are possible, for many of the problems facing physicists who are concerned with plasma radiation have to be studied under conditions which cannot be produced in the laboratory. For this reason the International Quiet Sun Years are of great importance.[1]

There is another period of the Sun which is important; this is a condition of slowly varying radio emission. It is observed that there is a change of intensity in the wavelength range between 1 centimetre and 1 metre. There is a close connexion between this varying component and sunspots; it was first noticed by observation of their day-to-day variations.

The rotation period of the Sun as viewed from the Earth is about 27 days, and most sunspots do not last through the whole of this period. There is, therefore, no correlation between the period of the Sun's rotation on its axis and the variation of the intensity of the radiations. This, however, is only part of the story, for it has been observed that a day-to-day variation extends over a period very much greater than that of the life of the sunspot. It was noted during the time of a solar eclipse that as soon as the Moon moved between the Earth and the Sun the decrease of level of the radiations was not regular. The rate of variation observed suggested that there were a number of sunspots where radiation was most intense; some of the areas coincided with the sunspots, but other areas were in no way connected with them. To investigate this, Australian radio astronomers constructed a radio telescope consisting of 32 parabolas. This gave a very narrow beam with which to scan the disk of the Sun, the beam width being some 3 minutes of arc. The variation in the radiation recorded showed that there were areas which corresponded to temperatures in the range of 400,000°K. to 1,000,000°K. The total extent of the Sun's corona is not known; though the Sun is wholly gaseous, its atmosphere can only be said to end when the density has fallen to

[1] The present International Year of the Quiet Sun (IQSY) began in January 1964, and will actually extend over two years ending in December 1965. It is a vast international project of great scientific significance.—EDITOR.

that of the gas in interstellar space. It seems that in the region of the Earth the density may be of the order of 9,000 protons (that is to say, hydrogen nuclei) and 9,000 electrons per cubic inch. Such a gas is very tenuous, but still much denser than that of interstellar space. The actual temperature may be as high as 100,000°K. The temperature is maintained by a still higher temperature of the corona itself. The gas near the Sun being much hotter, particles moving away from it will have greater energy than those that are moving towards the Sun. Of the energy of the outgoing particles, some will be given up to those particles coming in, so that heat will be passed across space by the process of conduction.

The transfer of heat by this method deals only with a small part, most of it being conveyed by means of electro-magnetic radiation – both visible and invisible. A certain part of the heat is conveyed by the process of convection. Compulsion of energetic particles directly from the lower atmosphere of the Sun at a time of violent disturbance, such as in the case of a flare, is the reason for this transfer; thus a direct contact is established between the atmosphere of the Earth and the outer corona of the Sun. Though conduction and convection are both concerned, it accounts for but a small fraction of the transfer of this heat; nevertheless, the particles which are accelerated by solar storms can disturb radio communications to a very marked degree. The linking of the two atmospheres gives rise to the continual turbulence in the ionosphere, and is part of the process of the development of the radiation belts known as the Van Allen belts.

The extent of the radio Sun can be measured by making use of another powerful radio source, the Crab Nebula. Since the Sun's corona should be able to absorb or modify the intensity of radio waves passing through it, it should be possible to detect the change in level of the radiations from the Crab Nebula as it is eclipsed by the Sun. Hewish, at Cambridge, confirmed that the Sun did, in fact, obstruct these radio waves from the Crab Nebula in 1951. Measurements made for a period of several weeks before and after the time of the eclipse enabled the extent of the corona to be

plotted. Confirmation was established not only of the modification of the radiations, but also that it was affected at the lower frequencies first. This agrees with other findings of the intensity of radiations from the corona, i.e. that the higher frequencies originate nearer the surface of the photosphere and the lower frequencies farther out. It is therefore of considerable importance to conduct observations of the eclipse of radio sources by the Sun throughout the period of the sunspot cycle. There is now evidence to suggest that the corona extends in a manner such that its greatest density lies in the plane of the Sun's equator, and investigations are being continued to add to the data.

The corona has also been studied by the use of radar techniques. If a radio wave can be modified in the manner shown by the Crab Nebula investigations, it follows that it must be possible for a radio wave to penetrate far enough into the ionized atmosphere of the Sun until a level is reached where the wave is reflected. However, such a radio wave would, of course, suffer considerable absorption as it passes through the ionized gas, due to collisions between the electrons and protons. With centimetre waves it is possible to penetrate very deeply into the solar atmosphere, where the gas is very dense; but absorption can then be so strong that the energy of the waves has disappeared before reaching the level of reflection. Successful radar studies have been made in the metre ranges of wavelengths, and a considerable amount of work has been done in this connexion. There are two major difficulties in obtaining radar echoes; the first is due to the high temperature of the thermal emissions, which makes it difficult for the echo to be distinguished amid the noise created by radiation at this temperature. Another difficulty is due to the Doppler effects which appear because of the rotation speed of the Sun – which is of the order of 3 kilometres per second, so that an echo from the limb moving towards the Earth would show a rise in frequency, or shorter wavelength, than the original signal, and on the side moving away the echo would show a longer wavelength. In spite of these limitations, the first successful radar echoes from the Sun were obtained in 1959 on a wavelength of 12 metres. These

and later measurements have shown that the corona is extremely irregular.

The importance of radio studies of the Sun has already been stressed previously where plasma physics are concerned, and during the next few years radio astronomers will have much to contribute to our knowledge of the Sun and its effect on the planetary environment. The Sun is a fruitful source of observation for amateur radio astronomers, because the radiation levels are high enough to be dealt with by comparatively simple apparatus.

The Astronautical Outlook

KENNETH W. GATLAND

In a triumphant wave of space activity in 1959, Russia passed, hit and circled the Moon with a series of unmanned Lunik probes. The third vehicle gave man his first glimpse of the far side of the lunar surface, by means of photographs relayed to Earth by television.

The flush of enthusiasm which followed these historic events led to speculation that man himself would quickly follow the path of the robots. In the Soviet Union there was talk of a seven-year programme to put the first men on the Moon, whilst in America design studies for massive launch vehicles being prepared by the National Aeronautics and Space Administration took on a new urgency.

The tenor of the 'Space Race' was set by the late President Kennedy before a joint session of Congress on 1961 May 25: 'I believe that this nation should commit itself to achieving the goal, before the decade is out, of landing a man on the Moon and returning him safely to the Earth. No single space project in this period will be more impressive to mankind, or more important for the long-range exploration of space, and none will be so difficult or expensive to accomplish.'

The announcement set in motion one of the most fantastic programmes of engineering development yet undertaken by mankind – Project Apollo. In this the Americans set themselves the task of providing a launch vehicle – Saturn 5 – with a lift-off thrust of 7·5 million lb. This vehicle is being developed to project a composite spacecraft of some 43 tons to the Moon, part of which will be a 15-ton secondary landing vehicle LEM (Lunar Excursion Module).

The plan is to send this combination vehicle into lunar orbit, whereupon the LEM will detach from the orbiting parent and soft-land on the Moon with two of the three-man Apollo crew.

To land, use will be made of VTOL techniques employing radar signals ranged against the surface of the Moon to gauge altitude in conjunction with a computer. At a fixed height the lunar let-down engine will fire to reduce the descent rate and, landing legs having been extended, the vehicle will complete a vertical descent on to the lunar surface, hovering for short periods before making the final touchdown.

After the scheduled period of stay on the Moon, the LEM vehicle will take off, using its leg-supported base section as a launch pad, and must complete a full rendezvous and docking operation in lunar orbit to transfer the crew for the homeward flight.

When NASA finally adopted this technique in July 1962 they had rejected two alternative methods. The first was the direct-flight approach which would have involved a Nova-type vehicle of 12 million lb lift-off thrust. Second was Earth-orbit rendezvous, which would have meant a docking operation between components of two Saturn 5's in a parking orbit around the Earth.

In theory both techniques would have projected a spacecraft of some 78 tons to a soft-landing on the Moon with provision for direct return. The heavier landing vehicle was the penalty to be paid for taking the entire propulsion machinery down on to the lunar surface and re-launching it.

Theoretically, therefore, use of a two-part spaceship which left the return engines and propellent temporarily in orbit around the Moon seemed an excellent proposition in that it considerably reduced the overall performance requirements for the mission. In so doing, however, the operation was complicated by the need for the small LEM vehicle, after rising from the Moon's surface to rejoin the parent spaceship in lunar orbit. The hazards associated with the problem of landing on the Moon were thereby markedly increased by the possibility of a missed rendezvous or some spacecraft failure which might result in the astronauts being stranded in

space remote from the Earth. The Americans have contented themselves with the argument that by the time they are ready to launch the Apollo Moonship the ability of two spacecraft to perform rendezvous and docking manœuvres will have been fully developed, in Earth-orbit, using two-man Gemini spacecraft and Agena D target vehicles.

Let us now turn to consideration of Soviet space plans. For some time we have had little more to go on than the semi-official statements of Soviet scientists which have generally been sufficiently vague to avoid giving any real clue to Soviet intentions, while maintaining optimism for the Soviet man-in-space programme and the Moon as the primary target.

Where unmanned probes are concerned, they have generally been regarded as essential devices for obtaining basic data for manned operations which are to follow. This has been a consistent attitude on the part of the Soviet Union ever since the Space Age began, whereas some authorities, particularly in Britain, have tended to view manned lunar exploration as an unnecessary extravagance. It is argued that orbiting and soft-landing robot probes could wrest from the Moon and the planets all the information that scientists wish to know, and that the task of adapting human explorers to alien environments is out of all proportion to their value aboard the vehicle. Television cameras can act as 'eyes' on the surface, seismometers can check for disturbances taking place in the Moon's crust; and Geiger counters can search for radioactivity. A whole range of instruments can be employed to obtain other types of information. Moreover, once the usefulness of the robot is finished, it can be abandoned without a qualm. It is even conceivable that robot probes, responding to remote radio commands, could land on the Moon, take off and return to Earth with samples of the lunar material.

To many scientists there is logic in the view that since in any event the human astronaut must depend on instruments to obtain his most vital information, it is best to eliminate him entirely from the scene of operations.

Against this it has been argued that the planetary probe at best

would have only limited intelligence; it can only return data of the type for which it has been instrumented. If it encounters some unsuspected phenomenon, the amount of analysis it can perform will be limited to the amount of analytical equipment its designers presumed it would need before it was launched.

The ultimate answer, however, may not be bound up at all with the limitations of robot techniques. Man is unlikely to rest content with second-hand experience. After all, he is the product of an evolution which began in space with the formation, from promordial gas and dust, of galaxies, stars and planets. Ultimately, he is a creature of the Universe, not merely of the Earth.

Apart from the need to develop robot spacecraft as pathfinders to the Moon and the planets, the emphasis throughout in the Soviet space-programme has been how to adapt man (and woman) to the task of interplanetary exploration.

It was not until the autumn of 1963 that an authoritative ray of light was permitted to fall on the future course of Soviet development. Speaking at the 14th Congress of the International Astronautical Federation in Paris on September 28, Yuri Gagarin confirmed that Soviet endeavours were being directed through the technique of Earth-orbit rendezvous.

A lunar expedition, he said, would probably last 10 to 14 days. Vehicles of 'several scores of tons' necessary for this mission could not yet be launched and it was possible that the problem would be solved in different ways.

Gagarin went on: 'Projects being worked out in my country involve the assembly of parts of ships in Earth-orbit and the introduction of propellent.' There are extremely complex problems affecting communications, optics and control. In the rendezvous and docking of two cosmic ships, techniques would depend on direct manual control and a great deal has been learnt from the group flights performed with Vostok spacecraft. He anticipated further flights of longer duration with mixed crews of scientists and cosmonauts.

Hardly were these sentiments uttered than Mr Khrushchov dropped his 'bombshell'. In an interview published in *Izvestia* on

October 26 he declared that: 'At the present time we do not plan flights of cosmonauts to the Moon. I have read a report that the Americans wish to land a man on the Moon by 1970. Well, let's wish them success. We will see how they fly there, and how they will land there . . . and how they will take off and return. Russia would take the U.S. experience into account. We do not wish to compete in sending people to the Moon without thorough preparation. It is obvious there would be no benefit from such competition. On the contrary, it would do harm, because it could lead to fatalities.'

In the West these words were generally interpreted by the newspapers as meaning that the Soviet Union was contracting out of the manned lunar project either for reasons of economics or technical difficulty, but later a different slant was placed on the matter by official Soviet news media. On November 6, Mr Khrushchov himself was reported as saying: 'We have never said we are giving up our lunar project,' and in an interview with the *Novosti* Press agency Gagarin stressed that, in contrast to the United States, no date for a Moon flight had been fixed in the Soviet Union. Many preliminary projects were on the agenda, he said, including the launching of guided spaceships able to change their orbits, the rendezvous and docking of spaceships, and the delivery of automatic devices to the Moon.

V. Ardatovsky, the agency's correspondent, concluded: 'As far as the Soviet Union is concerned, it has never set itself the aim of hurrying with man's landing on the Moon. From the very onset, the Soviet programme of space research has been based on a very different principle, and it still is. Planned work is in progress, definite stages are being reached, and each of these stages is necessary and obligatory for the next one.'

In other words, a project as complex as lunar exploration should not be regarded as a 'race' but should only follow the completion of carefully planned stages of technological development. It is the pace of these solutions which dictate the time when Russians or Americans will land on the Moon, and any outside considerations acting to by-pass them could be suicidal.

If this is really the Soviet conviction, then why not go one stage farther and combine the two national programmes?

A lead in this direction had, in fact, been given by the late President Kennedy. Addressing the U.N. General Assembly on 1963 September 20, he said: 'Why . . . should man's first flight to the Moon be a matter of national competition? Why should the United States and the Soviet Union, in preparing such expeditions, become involved in immense duplications of research, construction and expenditure? Surely we should explore whether the scientists and astronauts of our two countries – indeed of all the world – cannot work together in the conquest of space, sending some day in this decade to the Moon not the representatives of a single nation but the representatives of all our countries.'

At the time American engineers were incredulous. Had not the President himself set the ball in motion for the biggest engineering prestige contest of all time – and was not American industry now irreversibly committed to the national Moon programme?

Even if the Russians were willing to enter whole-heartedly into the spirit of international collaboration, how would such collaboration work? The popular conception of an American spacecraft going to the Moon on the nose of a Soviet booster represents no more than a caricature of the solution. First, in marrying the technology of East and West, there would have to be enormous changes in the Soviet attitude to the sharing of technical information and facilities.

This is in marked contrast to the situation as it exists at present, for the Russians have always been unwilling to open their research centres, plant and cosmodromes to Western observers. At the time of writing they have yet to show their own people a photograph of a Soviet sputnik or interplanetary probe in the act of being launched. Even in the official Soviet documentary film depicting the first orbital mission of Yuri Gagarin, *First Flight to the Stars*, history has been distorted by the substitution of a small ballistic rocket in the launch sequence. Clearly this is because the launch vehicle employed was derived from a large ICBM. Indeed, it has been inferred by Soviet speakers on a number of occasions

that the boosters which put Gagarin and his fellow cosmonauts into orbit are related to the global-range rocket which Mr Khrushchov claims can strike at any target in the world from any direction.

Asked during the Press conference for Valery Bykovsky and Valentina Tereshkova in June 1963, when Western correspondents would be allowed to witness the launching of Soviet cosmonauts, Academician M. V. Keldysh, President of the Soviet Academy of Sciences, commented:

'I should like to say that the American Mercury spacecraft weighs two tons, while ours weighs about five tons. That is why we fly farther and longer. But if our ship can orbit a payload of five tons, it can also orbit a military load of the same weight. So long as there are no guarantees of peace in the world, the Soviet people cannot reveal secrets concerning the country's defensive might. This question will be settled when there are firm guarantees of peace.'

One is therefore drawn inexorably to the conclusion that technological co-operation with the Soviet Union is impossible outside the context of an East-West disarmament agreement.

Despite the enormity of the problems involved, it is desirable that the West should use every opportunity to test the climate of Soviet opinion, for, particularly where co-operation does not involve the Russians revealing details of their launch vehicles, advances may yet be possible.

An encouraging sign has been the approval of a Memorandum of Understanding between the U.S. National Aeronautics and Space Administration and the U.S.S.R. Academy of Sciences for implementing a co-operative space agreement reached in Geneva in June 1962.

This agreement covered three distinct areas of co-operation: (1) Joint experiments with communications using the U.S. balloon-satellite Echo 2 from which radio signals can be reflected; (2) a co-ordinated weather satellite programme; and (3) joint contributions of satellite data to the World Magnetic Survey to be conducted in 1965.

None of these, of course, required the Soviet Union to disclose information on launch vehicle or satellite technology. Experiments with Echo 2 involved transmissions between the Zemenki Observatory of the Gorky State University in the U.S.S.R. and Jodrell Bank, England, using a frequency of 162 Mc/s. Transmissions from the United States were being sent by conventional means to Jodrell Bank for reflection to Gorky via the polar-orbiting balloon-satellite.

The basis of the co-ordinated meteorological satellite programme is the provision of a full-time telecommunications link between Washington and Moscow for the transmission of cloud pictures and other data from experimental weather satellites operated by each country. The Memorandum provides that other countries may receive such information from this link on a cost-sharing basis and, ultimately, this programme is to involve co-ordinated launchings of operational weather satellites.

In the magnetic field survey, each country will launch a specialized satellite equipped to measure the Earth's magnetic field. The effort will supplement the various ground, sea and aerial measurements undertaken during the World Magnetic Survey. The results will be exchanged and compared in order to obtain the most authoritative expression of the geomagnetic field.

So far so good. But how can we proceed from there? Obviously the way is open to increase the exchange of information obtained with scientific satellites, and it is not inconceivable that co-ordinated launchings can be arranged in the interests of synoptic observation. Why, then, should not the same principle be applied to the exploration of the Moon?

One might begin with an agreement to co-operate in researching the Moon with *unmanned* spacecraft. The importance of gaining the maximum amount of information concerning the Moon's surface before human landings are made is obvious and both Russia and America are launching soft-landing probes with this object in view.

In order to regularize these activities for the maximum benefit,

one might suggest the following for consideration not merely by Russia and America but by the world scientific community:

(1) Agreement to share all scientific information resulting from lunar exploration;
(2) International discussion on the selection of experiments for orbiting and soft-landing Moon probes;
(3) Co-ordination of launching attempts between the U.S. and U.S.S.R. with instrumented probes and co-operative use of East-West tracking and data-gathering facilities; and
(4) An invitation to other countries to assist in formulating experiments and providing scientific instrumentation for Moon probes launched by the U.S. and U.S.S.R.

Should the Soviet Union, at the present stage, feel unable to open her research institutions and cosmodromes to Western scientists, agreements might be worked out with the Academy of Sciences, on the one hand, and the National Aeronautics and Space Administration, on the other, whereby the scientists of Eastern bloc countries work with the Soviet Union and the scientists of Western countries work with the United States. An arrangement of this kind might be possible under agreements similar to those already established by NASA for the launching of international scientific satellites (e.g. the U.S./U.K. S-51, S-52 and S-53 series).

If such an agreement were reached in an atmosphere of improving East-West relations, it might then be possible to apply similar principles to co-operation in manned space exploration.

It is doubtful if this would involve the joint development of a particular design of spacecraft or launch vehicle – in any case, development would have gone too far for that! – but it could well result in a division of operational tasks. What then might be realized is a joint use of the nationally developed space hardware in a spacelift of supplies to obtain the first firm footholds on the Moon in the shape of a scientific base.

This would serve not only to unite the respective national space programmes and bring in the scientists of other countries, but it

would introduce real economies into an immensely costly supply operation. Moreover, the whole procedure would be made safer and more secure because launchings would be properly co-ordinated to ensure that if one vehicle should fail remote from the Earth other vehicles will be on hand to effect a rescue. At the present time nothing looks more hazardous than Moon-projects involving a single launch vehicle on which the demand is wellnigh 100 per cent reliability. Technically and economically, there is everything to gain from a combined logistics operation.

Measuring the Universe

HENRY BRINTON

In astronomy, we deal with vast figures of distances and sizes; so enormous are these, that the word 'astronomical' has become a synonym in the English language for 'immense' or 'inconceivably large'.

To those first becoming acquainted with the science it is a mystery how man, chained to his infinitesimal speck of Earth, has reached out with his puny measuring-rods into the utterly remote reaches of boundless space.

Before giving a bare outline of the principal steps in this exciting journey, it would be as well to explain that, in the main, the whole science of astronomy relies upon a system of mixed logic and extrapolation. We apply the principles which we have tested on Earth to those few heavenly bodies whose quantities we can directly measure. If the familiar principles hold good for these, we assume that they are universally valid.

In doing so, however, we are aware that this method has its limitations. Einstein, for instance, has shown that Newton's Laws of Motion do not hold good for velocities which approach those of light, and that Euclid's geometry is only valid in a special kind of space. It is because new knowledge often causes us to revise old ideas that astronomy sometimes has to turn back upon its tracks. In setting out, therefore, the basic 'facts' about the Universe in which we live, it is only prudent to recall that all science is an adventure along a road with many turnings.

The first serious efforts to measure the Universe of which we are a part were made by the Greeks. Aristarchus devised a most ingenious method for measuring the relative distances of the Sun and the Moon. A little later Hipparchus is said to have measured

the distance of the Moon; but, though these and other Greek astronomers devised some very delicate and ingenious methods, their work was of little practical use, as they seem to have regarded actual measurements as beneath their dignity. Aristarchus, for instance, gave the angle which the Moon subtends at the eye as 2 degrees, whereas any schoolboy can measure for himself that it is only about half a degree.

The first really practical measurement was carried out by the Alexandrian Greek, Erastosthenes, in about the year 200 B.C. He knew that Alexandria was due north of the town of Syene; and he knew the distance between the two places. By measuring the difference of the angle of the Sun at transit he found out, in effect, the distance of a degree of latitude and hence the size of the globe. It is worth noticing that he obtained a far more accurate result than that on which Christopher Columbus worked when he set out to travel to the Indies and found America by mistake.

It was many centuries later before Newton took the first and decisive step into outer space by making a brilliant assumption, which one might almost say has been the basis of all subsequent astronomy.

By his day the distance of the Moon had been measured with some accuracy by the method of parallax. This simply consists of measuring the apparent shift of the Moon against the starry background, when viewed from two different places on the Earth, the distance apart of which is known. To us it seems obvious that the forces with which we are acquainted, such as those which keep a motor-car on the road, are exactly the same forces as those which bind the planets in their orbit, and dictate the motions of 100,000,000,000 stars about the centre of the Milky Way; but in Newton's day it was an exciting and almost rash assumption.

Nothing could be much simpler than the calculation which is needed to check, as Newton checked, that we can account for the Moon's orbit round the Earth by the force of gravitation which brought down the apple in Newton's orchard.

Newton made the simple assumption that gravitation obeys the law of the inverse square; that is to say, that its force varies

inversely as the square of the distance from the centre of the Earth. If this be true, the gravitation due to the Earth at the distance of the Moon must be exactly in balance with the centrifugal force of the Moon in its orbit round the Earth. Purists will, of course, insist that there is no such thing as centrifugal force; but, whilst this is true, the mathematical results of treating centrifugal force as though it were a real thing gives the right answers. One other, and this time a false, assumption has to be made; and that is that the Moon revolves round the Earth, whereas, in fact, of course, they both revolve about the barycentre – or the combined centre of gravity of the Earth-Moon system. But, as the barycentre is within the Earth's surface, the difference can be neglected for this kind of calculation.

Newton knew that the distance of the Moon was near enough to sixty times the radius of the Earth. If, therefore, one multiplies the force of gravity at the Earth's surface by one-sixtieth squared, the result is the force of terrestrial gravitation at the centre of the Moon. If Newton's guess was right, this figure should equal the centrifugal force of the Moon in its orbit, which is $\frac{mv^2}{d}$, m being the mass, v the velocity and d the distance from the centre of the Moon to the centre of the Earth. Since one can take a particle of unit mass at the Moon's centre, one may say that $\frac{v^2}{d}$ should equal $\frac{g}{60^2}$ or $\frac{g}{3{,}600}$, where g is the gravitation at the Earth's surface. The sum is a very simple one to work out, and one may check Newton's calculation for oneself with great ease.

The next great step was that of weighing the Earth, which was done in 1798 by Cavendish. It had already been postulated that any two masses attracted one another by the product of their masses divided by the square of their distance apart; but until some particular gravitational system had been measured, it was impossible to make use of the knowledge to weigh bodies outside the Earth's gravitational field. What was needed was the constant which needs to be applied, and this was obtained by Cavendish's

experiment, which consisted, in principle, of measuring the attraction exercised between heavy metal spheres. One does not know whether to admire more the ingenuity of the experiment, or the delicacy with which it was carried out. The result gave the mass of the Earth as $5{\cdot}98 \times 10^{27}$ grams, and G, the universal constant of gravitation, as $6{\cdot}670 \times 10^{-8}$.

The next step was in using this information to determine the dimensions of the Solar System. Kepler had already shown that, in the case of the planets, the square of the orbital period varies as the cube of the distance from the Sun. From this it is easy to derive the relative distances of the planets from one another and from the Sun, but the absolute distances depend upon obtaining a scale.

This can be done if, and only if, one knows the distance between any two of the bodies concerned. The problem was eventually solved by measuring the distance of the planet Mars, making use of the method of parallax. The distance of Mars, however, is so great compared with the diameter of the Earth that the result so obtained was only approximate. Later methods gave more accurate results by measuring the distance, through the method of parallax, of one of the minor planets or asteroids. Very recently indeed a more exact scale has been obtained by reflecting radio signals from the planet Venus and measuring the time the signal takes to go out and come back again.

Once the distances of the planets had been established, it was possible to set about ascertaining their masses. This is very easy to do in the case of those planets which have small satellites. Once the distance of a planet is known, say Jupiter, it is easy to calculate the distance and velocity of the orbit of one of its satellites. An amateur with a relatively small telescope can do this for himself given only the distance of the planet. The calculation itself is easy enough. Once again one can employ the concept of centrifugal force which is calculated from the size of the satellite's orbit and the time it takes to make one revolution round the parent body. This force must exactly equal the gravitational attraction of the planet itself and which, at the satellite, is equal to the mass of the

planet multiplied by the universal constant of gravitation and divided by the square of its distance from the satellite.

In the case of planets such as Mercury and Venus, which have no satellites, we are able to calculate their masses only by observing how much their orbits are perturbed by the nearest passages of planets whose masses we do know. This method is very approximate, and we still have no accurate figures for the masses of either Mercury or Venus.

When we move outside the Solar System our task becomes more difficult. Once the distance of the Earth from the Sun had been measured with accuracy, a large base-line was available for measuring, by the method of parallax, the distances of some of the closer fixed stars. It should be possible by observing the apparent shift of the nearer stars against the farther stars, as measured at six-monthly intervals, to derive a distance. Many efforts were made without success, and this is hardly surprising, as even using the huge base-line of the Earth's orbit round the Sun, the shift in parallax of even the nearest fixed star is very small indeed. It is about equivalent to trying to measure the size of a penny 12 miles away. However, with more modern instruments it has been possible to measure the distance of quite a number of stars in this way.

The movement of the Sun itself amongst the other stars provides another measuring-rod. As the Sun progresses on its everlasting journey through the stars of the Milky Way, the nearer stars can be seen to shift their apparent positions against the background of the more distant ones as judged from year to year.

For the next step in measuring the Universe we must go back to Newton. It was Newton who, through his work on light, laid the basis of modern spectroscopy. It is everyday knowledge that the temperature of a hot body is related to its colour. A poker in the fire first becomes a dull red, then bright red, and finally white. When the light of a given star is split up into its constituent parts it is possible to deduce the exact surface temperature of the star in question. When this was done with some of the nearer stars

whose distances had already been measured it was possible, of course, to measure the sizes of the stars. Given that one knew the star's distance, its apparent brightness and its surface temperature, there is a simple calculation to work out its size.

The next outward step into space was taken as the result of an observation which nobody has yet been able to explain. Among the variable stars there is a class known as Cepheids, whose behaviour is perfectly regular. It has been found that the longer the period of a Cepheid, the greater its real luminosity. If one knows how bright a star really is and how bright it appears, one can at once deduce its distance; Cepheids therefore act as standard candles among the stars. Making use of this peculiarity of the Cepheids, and the related so-called RR Lyræ stars, Harlow Shapley in America, some 40 years ago, was able to establish the shape and size of our own Galaxy, the Milky Way, which is approximately 100,000 light-years in diameter. Using the same methods and the giant telescopes, it has even been possible in this way to determine the distances of some of the comparatively close galaxies.

Though this use of the Cepheids has enabled us to measure otherwise unmeasurable distances, their story also provides a warning. Owing to an early confusion of types, some staggering results were arrived at. It appeared, at one time, that the Earth itself was older than the Universe of which it is a part! The confusion was cleared up, and distances were doubled overnight. Probably our scales are now at least approximately correct; but that such a confusion could arise should warn us that many of the figures given in astronomy are based on assumptions that are not necessarily true.

Reaching still farther out, very large telescopes have been able to make out exceptionally brilliant stars known as supergiants in more remote galaxies. If we make the very reasonable assumption that supergiants in these systems are on average of the same luminosity as supergiants in our own Galaxy, we can estimate their distances, and thus discover the distances of at least the relatively close galaxies.

The next and last step outward has been made once again by the use of spectroscopy through what is known as the Doppler effect. When a train goes through a station, whistling as it goes, it is a matter of common observation that the note of the whistle is higher as it is approaching and lower as it recedes. This is because when the source of the sound is approaching each wave starts a little closer to us than the previous one. Much the same effect is found with light. Light from a star which is rapidly approaching us is bluer than it would otherwise be. Conversely, it is redder if the star is going away from us. By measuring the amount of the shift in the spectrum it is possible to deduce the velocity of the star in question.

When the spectra of the nebulæ were examined it was found that, almost without exception, the light was reddened; that is to say that all the galaxies were apparently flying away from us and from one another. It was discovered, moreover, that the speed of recession was almost exactly proportional to the distance of the nebula. On this basis it was possible to calculate the distance of any nebula by the amount of the reddening of its light.

As measured in this way, the farthest object which we have so far been able to measure, 3C-147 in Auriga, appears to lie at a distance of no less than 6,000,000,000 light-years from us, and is receding at almost 90,000 miles a second, which is roughly half the velocity of light. Preliminary measurements with radio telescopes suggest that we are already able to receive signals from other galaxies perhaps half as far away again; and it may be that we are not very far from reaching the observable fringes of the Universe. However large and powerful our instruments may be, there comes a limit beyond which we can go no farther. At a distance of something like 10,000,000,000 light-years a galaxy would be receding so fast that its light would not reach us at all.

Astronomy is now facing perhaps one of its largest puzzles. If all the galaxies are flying away from one another in this regular manner, it follows that at some earlier period they must all have been grouped together in a single primæval atom. If this original condensation of matter, or primæval atom, call it what you will,

were in a state of equilibrium, it is difficult to see what force could ever have started it moving. If it was not in a state of equilibrium, somehow the matter must first have come together before it started to disperse. So far this is a problem which has baffled us. A solution has been suggested which is known as the Steady State Theory of the Universe, which postulates that the Universe is infinite and becoming more so as the galaxies recede. New matter is constantly being created and condensing into galaxies to fill up the spaces left by the recession of neighbouring galaxies. This theory, too, has its difficulties – apart from being incomprehensible to the ordinary mind. It may be, however, that we are on the verge of a solution, and that this solution will be provided by the new tool of radio astronomy in measuring the outer fringes of the Universe, discovering the exact distributions of the galaxies. However this may be, we may be reasonably sure that fresh problems will face us as older ones are solved.

Peculiarities Among the Cool Stars

BRIAN WARNER

Introduction

A glance at a representative selection of stellar spectra will show an enormous diversity. The hot stars show only a few spectral lines, usually dominated by the hydrogen lines. As we look at cooler and cooler stars the number of lines increases, until in the coolest stars the spectrum is filled up with lines and bands arising from the atoms and molecules respectively in the stellar atmospheres. In these coolest stars the hydrogen lines have virtually disappeared, and lines entirely different from the few visible in the hottest stars have appeared. Despite this complexity, modern astrophysical methods show that nearly all stars have the same chemical composition: virtually all of the spectrum differences can be attributed to differences in temperature (and, to a lesser extent, pressure) in the atmospheres of the stars. Thus at high temperatures all molecules are dissociated and atoms are ionized (i.e. at least one electron has been removed from the atom). The spectral lines of ionized atoms are mostly in the far ultra-violet, so we see very few lines in the visible region. In the cool stars neutral atoms and molecules abound, all with strong absorption lines in the visible region.

However, it is a rather fortunate circumstance that not all stars have the same chemical composition. By studying deviations from normal element abundances (the Sun may be taken as normal) we are able to deduce some properties of the deep interiors of stars, or of the materials out of which the stars were formed. Abundance peculiarities can be found in stars of almost all temperatures, but we will restrict ourselves here to discussion of the ones cooler than the Sun (5,800°K.).

Apart from differences in chemical abundances there are minor variations in physical structure. Thus some cool stars, mostly long-period variable stars, show a few emission lines as well as a normal absorption spectrum. This is interpreted as indicating that these stars have rather more extensive chromospheres than normal, and this is to be expected when one realizes that the variable stars are throwing off part of their atmospheres into space and surrounding themselves with a low density envelope of gas.

The loss of matter from stars is recognized by the presence of doubling of some of the strongest spectrum lines in the coolest stars. Thus the H and K lines – strong lines due to the occurrence of ionized calcium in the stellar atmosphere – frequently show two components, one with a normal wavelength and one displaced to shorter wavelengths. This is interpreted in the following way. Matter is being thrown off of these stars, causing an expanding shell of gas around the star. Light from the star itself has to pass through this shell on its way to us, and so an absorption line is produced, not only in the main part of the atmosphere, but also in the shell. As the gas in the shell is moving towards us, the Doppler Effect shortens the wavelength of the absorption line produced in the shell.

Although a very minor effect in the spectra of the brighter cool stars, this observational evidence for mass loss has far-reaching consequences. It is in this way that the star sends back into space most of the gas out of which it originally formed, except that the gas no longer has its original composition – it has been processed by nuclear reactions going on inside the stars. Thus the gas in interstellar space is constantly being renewed, and its composition changes with time. In fact, the proportion of helium (and maybe also the heavier elements) with respect to hydrogen is increasing all the time. We happen to live at a time when this process has reached the quarter-way mark: about 25 per cent of the Galaxy's initial hydrogen content has been turned into helium.

The Carbon Stars

Perhaps the most immediately obvious of all late-type (cool)

peculiar spectra are those of the carbon stars. When the system of spectral classification was being set up at Harvard at the end of the last century it was noted that among the late-type stars a few had strong absorption bands in the blue-green region of the spectrum (around 4,700–4,800 Å). Normal stars had no trace of these bands. According to the general colour of the star, these peculiar stars were designated R and N, with N the more red of the two. It was not long before it was recognized that these bands are due to the carbon molecule C_2, the particular bands in question being known as the Swan bands (there are others also due to C_2 in the red spectral regions). Hence the R and N stars became known as carbon stars, and are frequently called C stars. Apart from bands due to other carbon compounds (e.g. CH, CN, C_3) there is little other molecular absorption. As might be expected, determinations of the abundance of carbon in these stars showed it to be considerably higher than in normal stars. Furthermore, additional bands were discovered in the carbon stars which are due to the carbon isotope C^{13}. The normal Swan bands arise from a molecule composed of two C^{12} atoms, but near them are bands coming from the molecules C^{12} C^{13} and C^{13} C^{13}. We can therefore make an estimate of the abundances of both carbon isotopes in the atmospheres of the carbon stars. It turns out that in normal carbon stars (there are some peculiar ones!) the ratio C^{12}/C^{13} is around 4, whereas on the Earth and in the Sun it is about 90. We will discuss the significance of this later.

As a group, the normal carbon stars appear to be comparatively young. They are associated with Population I normal stars; they are concentrated in the galactic plane and a few are found in young galactic clusters. They appear to be mostly giant stars. A few high-velocity (Population II) carbon stars are known (these are all R stars), and like the normal Population II stars they show deficiencies in metal abundance.

The Heavy Metal Stars

Another type of peculiar cool star was designated S. These resemble the normal M stars in having a lot of molecular absorp-

tion, but instead of the usual titanium oxide (TiO) bands there are in addition zirconium oxide (ZrO) bands. The pure S stars show ZrO without any TiO, but there is a complete gradation between the S and M stars in relative amounts of ZrO and TiO. The S stars also show the absorption bands of carbon, but not as strongly as in the carbon stars.

Associated with the S stars are the barium stars. These, it would seem, are the higher temperature analogues of the S stars. As the name suggests, the absorption lines due to barium are strong in the Ba stars, and this is also a property of the S stars. In fact, the S and Ba stars show strengthening of the lines of C, Ba, Sr, and most of the rare earth elements. For this reason they are collectively called the heavy metal stars. Roughly speaking the Ba stars show the same relationship to the S stars as the R stars do to the N, namely that the Ba and R stars have surface temperatures similar to the late G and K giant stars (4,500–3,500°K.), and the N and S stars similar to that of the M stars (3,500–2,000°K.).

Like the C stars, the heavy metal stars are Population I objects, though one high-velocity Ba star is known. The S stars, in particular, cluster around, or in, associations of hot O and B stars, showing that they are among the youngest known stars.

Interpretation of the Spectra

An attempt was originally made to see if the peculiar spectra of the S stars could be explained solely by unusual *physical* properties of the atmospheres of these stars. It was found that no combination of temperature and pressure could cause effects like those observed, and the conclusion was that there must be real overabundances of the heavy elements in the atmospheres of these stars. However, the strange lack of TiO in the S star spectra has a particularly instructive explanation. It might be thought that this would indicate an underabundance of either Ti or O. Yet other oxides (ZrO, YO, LaO) are plentiful in the S stars, and the lines from Ti itself are not weakened with respect to M stars of the same temperature. There must, therefore, be a mechanism that

inhibits the formation of TiO in the S stars, and the same mechanism must be responsible for the absence of TiO bands in the C stars.

The key to the problem is the overabundance of carbon in the C and S stars. In a stellar atmosphere there is fierce competition amongst the atoms of C, Ti, Zr, etc., to form molecules with oxygen. It turns out that carbon has by far the greatest affinity for oxygen and therefore dominates the acquisition of oxygen atoms. Now in normal stars oxygen is about four times as abundant as carbon, so that even when all the carbon has been used up in the formation of CO there is still plenty of oxygen to go round and TiO can be formed. Incidentally the CO bands are in the far infra-red and so do not dominate the visible spectrum of normal stars. In the N stars, however, carbon is about twice as abundant as oxygen, and therefore secures all the oxygen and none is left for TiO, etc. In S stars the C to O ratio is about unity, so a little TiO can be formed. The strength of ZrO in the S stars is a combination of this same effect, together with an overabundance of Zr. There are one or two stars known where all oxide bands and the C_2 bands are weak, and it is presumed that here the C and O abundances exactly balance!

Interpretation of the Abundance Anomalies

So far we have not discussed the reasons why there should be overabundances of carbon and the heavy elements in these cool giant stars. Before we can do this we must examine the interior structure of such stars.

Theoretical studies, in combination with observational evidence from the Hertzprung-Russell Diagram, have shown that the interiors of the cool giant stars are not uniform in chemical composition. In the centre is a dense core of almost pure helium – resulting from conversion of hydrogen to helium in the earlier stages of the star's life. Surrounding this is an extensive envelope of gas with a normal hydrogen and helium content, together with quantities of the other elements. Around the core is a thin layer where the conversion of hydrogen to helium is still going on,

supplying the energy by which the star shines. The temperature of the core (which is isothermal) is near 10^8°K.

Now, the temperature of the core is such that some helium is converted into carbon. It is suggested, therefore, that the convection currents which are known to exist in the envelope mix this carbon (together with some helium) to the surface of the star, where we see it. The carbon brought to the surface in this manner would be C^{12}, but on its way through the hydrogen-burning shell this would be mostly converted into C^{13}. The agreement with observation is surprisingly good, because the equilibrium ratio of C^{12}/C^{13} in the C-N cycle (which is going on in the hydrogen-burning zone) is about 4 according to theory, and this is precisely that observed (see above).

In addition to this, our knowledge of nuclear physics tells us that if some of the envelope material were to mix with the hot helium core nuclear reactions would ensue that would produce a large flux of low-energy neutrons. These neutrons collide with the heavy elements (especially iron) and form heavier elements. The outcome of all this is that certain heavy elements get built up preferentially. These are then mixed to the surface together with the carbon.

The test of this hypothesis is whether the predicted overabundances (i.e. predicted from the constants of nuclear physics) agree with what is observed. Qualitatively the S stars agree with the nuclear theory, but it is impossible as yet to determine accurate abundances in these stars. However, the Ba stars, which have undergone similar interior mixing processes, can be analysed. Ten of these stars have been analysed by the writer and the agreement with nuclear theory is very good indeed.

We may claim, therefore, to at least know what processes have produced the peculiar abundances in these cool stars. At the moment we are still not sure whether the same thing happens to all stars at some time in their life, or whether the R, N, S and Ba stars are alternative paths of evolution for a few stars. What seems most probable at the present time is that the interiors of all cool giant stars have the heavy element overabundances, but it is

only a few stars that we are privileged to observe this. For instance, it could be that the interior convective currents do not usually quite reach the surface of the star, so most stars have atmospheres of normal composition. Then a very small increase in convective activity in just a few stars (about 1 per cent of all cool stars) could carry the interior matter to the surface. On the other hand, the Ba and S stars may be stars which have lost most of their atmosphere through mass-loss into the surrounding space; we are then looking at what was once the interior material.

Other Cool Peculiar Stars

A very few stars are known which do not fit into the normal C or Ba and S categories. These are then really peculiar stars, though from what has been said above it can be seen that the carbon and heavy metal stars may not be so peculiar after all.

Mention has already been made of the high-velocity R stars (these are known as CH stars on account of the dominating strength of the absorption bands due to the CH molecule). In addition there are a few carbon stars known which are deficient in hydrogen. This is shown by the very weak hydrogen absorption lines and the disappearance of the CH bands, whereas the C_2 and CN bands are strong. It is thought that these stars are carbon stars in an advanced stage of evolution, having converted nearly all of their hydrogen into helium and the heavier elements.

Just three carbon stars are known that have a large overabundance of lithium. These pose a difficult problem, because Li is consumed in a hydrogen-burning zone, so the surface material of these stars cannot have come from the interior. It is possible, however, that the Li has been formed on the surface of the stars since the carbon-rich material was brought up.

Finally, to complete the picture, there are carbon-poor stars. These lack CH and CN bands, but have a normal H content. The explanation of these (two) stars remains obscure.

Conclusion

It can be seen that, although very rare, the cool peculiar stars

are worthy of the closest attention. They provide us with an insight into the processes occurring in the interiors of the cool giant stars – something which is not directly possible by a study of the normal stars. Not only do they provide us with checks on the correctness of our theoretical models of the interiors of the more normal stars, but at the same time one is able to check the consistency with nuclear theory. In fact, it has been possible to actually predict certain nuclear constants (cross-sections for neutron collisions, for instance) from observations of the Ba stars that are rather better than some of the laboratory-measured values. If this seems surprising it must be remembered that the interior of a star is nothing more than a vast nuclear reactor, working at temperatures and pressures not attainable in the laboratory.

It is for all of these reasons that the literature of astronomy is filled with studies of peculiar stars. The study of extreme cases frequently provides insight into the working of the normal types. Although about 95 per cent of stars can be regarded as normal, it is the 5 per cent minority that furnishes the most rewarding results.

Recent Advances in Astronomy

PATRICK MOORE

It is rare nowadays for many months to pass by without some spectacular new developments in astronomy or space research. So far as the direct exploration of space is concerned, the twelve months prior to July 1964 had been rather uneventful. The U.S. vehicle Ranger VI crash-landed on the Moon in January, coming down in the grey plain of the Mare Tranquillitatis, but its cameras failed to function, while the Russians had contented themselves with sending up a planetary probe which they called Zond-I, but about which little more was heard. Then, at the end of July, came the greatest American success to date.

Ranger VII, like its January predecessor, was designed to land on the lunar surface and send back photographs during the quarter-hour prior to impact. On this occasion everything worked perfectly. The launching was accurate; a mid-course correction to the orbit was made, but no terminal correction was needed, and the rocket plummeted down near Guericke in the Mare Nubium, within a few miles of its intended position. Communications were good throughout, and more than 4,000 pictures were received. The last photograph was still being transmitted when Ranger VII struck the Moon and was destroyed. The picture shows an area comparable in size with a tennis-court, with craters a mere 3 feet in diameter and 12 inches deep.

The most important result of the flight has been a final disproof of the theory due to T. Gold, according to which the lunar seas were dust-oceans. Had Gold been right, a manned landing on the Moon would have been a very hazardous business; the astronauts would have been in danger of vanishing permanently into a dust-drift more treacherous than any quicksand. Practical lunar

observers had had little faith in Gold's theory, but it had to be checked, and from all the available evidence it now seems that the lunar surface will be firm enough to support the weight of a spacecraft.

There seems to be little really level ground; even the apparently smooth parts of the Moon are covered with mounds and pits which constitute potential hazards to astronauts. The general view is that the main rôle in surface moulding was, after all, played by volcanic action and not by meteoritic bombardment. Secondary impact craters would, of course, be produced during the outbreaks which caused giant formations such as Copernicus.

This ties in well with some interesting observations made by James A. Greenacre and his colleagues at the Lowell Observatory, Flagstaff (Arizona) on 1963 October 30 and November 27. Greenacre witnessed a coloured phenomenon in the region of the brilliant crater Aristarchus. The observations of October 30 showed three patches, one inside Aristarchus and the other two close to the long winding valley sometimes called the Herodotus Cleft and sometimes Schröter's Valley. None lasted for as long as an hour, and no confirmatory photographs were obtained, but on November 27 Greenacre saw another red patch on the rim of Aristarchus. Other observers at Flagstaff and the Perkins Observatory were able to confirm it; the duration of the colour amounted to about an hour and a quarter.

The telescope used by Greenacre was the famous 24-inch Lowell refractor, which has been engaged mainly on the lunar mapping project sponsored by the United States Air Force. In May, Greenacre presented a full report at the Conference on Lunar Geology held in New York, organized by the New York Academy of Sciences and attended by lunar specialists from all over the world. There was considerable discussion about the origin of the patches. J. Green, the Conference chairman, suggested that the cause might be actual emissions from the lunar crust; I put forward the alternative view that the patches might be due to coloured deposits catching the sunlight under ideal conditions of lighting and libration. Close and continued observation of the

Aristarchus region will, it is to be hoped, clear the matter up.

So far as the origin of the formations is concerned, the opinions expressed at the Conference turned back to vulcanism rather than impact. It was also pointed out that recent surveys have cast grave doubts upon the meteoritic nature of some terrestrial features, such as the New Quebec and other Canadian craters, and the Vredefort Ring in Africa.

The lunar mapping project is being continued at Flagstaff, and the results are most satisfactory. Unfortunately, the military authorities insist upon a reversal of orientation, so that charts are now printed with north at the top; east and west have been reversed in meaning; for instance, the astronautical method is to put Mare Crisium near the *east* limb of the Moon. To make matters really chaotic, the team at Tucson, Arizona, has published charts in which the established lunar nomenclature has been altered, crater names being transferred, added and changed in a quite arbitrary fashion. There is now an urgent need for an international agreement upon lunar nomenclature.

No further planetary probes were launched before mid-1964 apart from the Russian vehicle Zond-I, about which few details have been published (evidently it was a Venus probe). However, on 1964 February 21 J. S. Strong and his colleagues at the John Hopkins University, in the United States, carried out studies of Venus, using spectrographic equipment in an unmanned balloon which was launched from the Holloman Air Force Base in New Mexico and rose to 87,500 feet. It was found that water-vapour in the atmosphere of Venus was definitely present, confirming the earlier results obtained in 1959 by C. B. Moore and M. Ross. It was found that the amount of H_2O in Venus' atmosphere is equivalent to a layer of liquid water 98 microns (0·0039 inch) deep, with an uncertainty of only $\pm$ 5 per cent. Strong thereby suggested that the clouds of Venus might, after all, be composed of H_2O. This does not agree well with the results obtained from the Mariner II probe, and it is clear that our knowledge of Venus as a world is extremely slight. Further investigations will have to be made before any definite conclusions can be drawn.

Of new professional radio telescopes, the most spectacular is that at Arecibo, in Puerto Rico, which has now been brought into operation. The instrument is located in a gigantic natural bowl which was re-shaped to be a segment of a sphere of radius 870 feet, lined with reflecting mesh to give a surface 1,000 feet in diameter. The dish is of course fixed, and points directly to the zenith, but its sophisticated feed system permits the telescope to operate as far as 20 degrees from the overhead point. Radar contact with Mercury was established in 1964 April 7 and 8, when the planet was 80,000,000 miles away. This is a major achievement indeed. (So far, the most distant object from which radar echoes have been obtained is Jupiter, which has been studied by Russian scientists in this way.)

At Arecibo, attention will naturally be paid to the remarkable objects known variously as quasars, quasi-stellar objects, or simply as QSOs. Much has been heard about these objects, but at the moment we have to confess that we have little idea of their true nature.

A QSO gives the impression of being a faint bluish star, but in fact it is something much more dramatic. It seems, indeed, that QSOs have the highest energy output of anything known in the universe. They are very small compared with ordinary galaxies, but are more than a hundred times brighter than the most luminous galaxy known, shining with a thousand million times the output of our Sun.

Since the QSOs are apparently dim, they are clearly very distant. 3C-147, in the constellation Auriga, has the largest red shift measured to date—even greater than that of the normal galaxy 3C-295 in Boötes, which formerly held the distinction of being the most remote object ever seen. Precise values cannot be given as yet, but 3C-147 must be something like 6,000 million light-years away, so that we are seeing it as it used to be before the Earth existed as an independent body.

The most luminous of the QSOs is 3C-273, which is more than 200 times brighter than our own Galaxy. It has a visual magnitude of 12·7, and so is visible in a moderate telescope; its position is

R.A. $12^h\ 27^m$, declination $+\ 02°\ 22'$. Its distance from us exceeds 1,500 million light-years.

The amazing energy given out by the QSOs is a complete enigma. It can hardly be due to exceptional abundance of supergiant stars, as in this case the angular diameters of the QSOs would be much greater than they actually are. Chains of supernovae have also been suggested, but this seems improbable; supernovae are rare in any particular galaxy (only three have been recorded in our own system—those of 1054, 1572 and 1604), and why should one supernova 'trigger off' another? More promising, perhaps, is the idea of gravitational collapse. This involves a 'star' of fantastic size, perhaps 100 million times as massive as the Sun, which would collapse under its own gravity, and, so to speak, explode inwards. Hoyle and Fowler had indeed discussed the properties of such a collapsing body about a year before QSOs were discovered. Obviously, this whole concept involves serious difficulties, but the energy of the QSOs must be explained somehow or other, and it is clear that we are dealing with energy sources which have been previously unsuspected.

Radio studies are, of course, all-important with investigations of QSOs, and it is unlikely that the true nature of these objects could be established by any other method. Research is still in its early stages, and all that can be said at the moment is that a QSO may well be the nucleus of a galaxy of peculiar type. 3C-273 definitely consists of two parts, as was established by Australian workers using the 210-feet radio telescope near Sydney. As the QSO was occulted by the Moon, the radio signals decreased in two stages, but at the end of the occultation the signals returned at the same moment. The positions of the two parts of the QSO could then be found, and agreed perfectly with the visual photographs taken with the 200-inch Palomar reflector.

Needless to say, the QSO studies have entered into the continuing controversy about the universe as a whole; there is still no agreement between the supporters of the evolutionary theory, and those who believe that the universe is in a steady state, with matter being continuously created out of nothingness. Arguments

and counter-arguments are being put forward all the time, but the solution to the problem seems to be as far away as ever.

One attractive theory, very popular in recent years, now seems to have been overthrown. It has been supposed that some of the radio sources beyond our own system are due to colliding galaxies; direct collisions between stars would be very rare, but the interstellar gas and dust would be colliding all the time, so producing the radio emissions. Doubts had been expressed by some Russian astronomers, who considered it more likely that the objects concerned were simply galaxies in the process of fission, but the basic idea of colliding galaxies was regarded as well established.

However, new investigations have demonstrated that the energy available from such a process would be quite insufficient to give rise to the radio emissions observed, and there seems no course but to abandon the whole collision theory. Unfortunately nobody has yet been able to find a substitute, but studies of QSOs may well provide some invaluable clues before long.

When we consider the vast amount of information now available to astronomers—even though many basic problems still puzzle us—it is remarkable to reflect that the telescopic era began not much more than three and a half centuries ago. Before that time, observations had to be carried out with the naked eye alone, which imposed a crippling limitation. The first man to use a telescope in astronomy was Galileo, who made his preliminary observations in the winter of 1609–1610. Galileo was born in February 1564, and his quatercentenary was therefore celebrated during the past year.

Meetings to honour the quatercentenary were held in many countries; in London, a special celebration was organized by the Royal Astronomical Society and the British Astronomical Association.

Galileo was one of the first, if not the first, to observe sunspots with the aid of a telescope. He also observed Saturn's rings, though not clearly enough for him to decide just what they were; he believed that Saturn must be a triple planet, and was perplexed when the two attendant bodies disappeared later on. Both these

observations are relevant to the year 1965. During 1964, the Sun had reached the minimum of its cycle of activity; some spots were seen, but often the disk appeared blank. By mid-1965 activity should be well on the increase once more, and the next maximum may be expected around 1969. This may well be regretted by space-researchers, since emissions from solar flares constitute a potential hazard to astronauts travelling beyond the protection of the Earth's atmosphere.

As for Saturn, it is worth noting that the rings are now closing up. For some years past the planet has been a magnificent sight, with its rings well displayed, but by 1966 the ring-system will be edge-on, and will be relatively unspectacular, as it will appear as a thin bright line projecting to either side of Saturn's disk. Small telescopes will not show the rings at all, and we can well understand why Galileo, with his feeble 'optick tube', lost sight of them.

Meanwhile, it seems that the next year is going to be of exceptional interest to both astronomers and space-researchers. Spectacular developments are certain. The U.S. moon-rocket programme is now well under way, and it has been announced that two unmanned probes to Mars will be sent up about October 1964; by the time that this Yearbook appears in print, the probes will be millions of miles out in space. The general plan is to land an instrumented probe on the Martian surface about 1967, though this will be a very difficult matter. Neither is it probable that the Russians will allow 1965 to pass by without some new achievement. It is impossible to make an accurate forecast of what will have happened before 1965 draws to an end.

PART THREE

For Stellar Observers

Most amateur observations are concerned mainly with the bodies in the Solar System. This is natural enough, since there is a wide field available. So far as the stellar heavens are concerned, only in variable star work can the amateur hope to make really useful contributions – unless, of course, he is lucky enough to discover a nova!

Yet there is immense pleasure to be gained by looking at the various stellar objects, ranging from binaries and coloured stars to clusters and nebulæ. In previous *Yearbooks* we have given lists of such objects, together with descriptions of what is to be seen. For the present issue, a condensed list is given, and it is suggested that there will be much useful information gained from going straight through it, observing the objects concerning to 'see for yourself'. For this reason we have tried to make the list as varied as possible.

Following this, James Muirden has produced a special article upon clusters and nebulæ, together with maps which should enable the objects to be found without much difficulty. Since Greek letters are used in his maps, the Greek alphabet is given for reference:

α Alpha	ϵ Epsilon	ι Iota	ν Nu	ρ Rho	ϕ Phi
β Beta	ζ Zeta	κ Kappa	ξ Xi	σ Sigma	χ Chi
γ Gamma	η Eta	λ Lambda	o Omicron	τ Tau	ψ Psi
δ Delta	θ Theta	μ Mu	π Pi	υ Upsilon	ω Omega

The lists do not pretend to be exhaustive; but they will, we hope, serve as a useful introduction to stellar observing.

Some Interesting Telescopic Objects

Object	R.A. *h*	R.A. *m*	Dec. °	Dec. ′	*Remarks*
Alpha Cassiopeiæ	0	38·5	+56	20	Fine orange star. Mag. 2·2; perhaps var.?
M31 Andromedæ	0	40·7	+41	05	Great Galaxy, visible to naked eye.
H.VIII 78 Cassiopeiæ	0	41·3	+61	36	Fine cluster, between Gamma, Kappa Cas.
Gamma Cassiopeiæ	0	54·5	+60	31	Pseudo-nova; mag. range 1¾–2¾.
M33 Trianguli	1	31·8	+30	28	Spiral. Difficult with small apertures.
Gamma Arietis	1	51·5	+19	07	Easy double; mags 4½, 4½; 8″·4; 000°.
Alpha Ursæ Minoris	1	58·6	+89	06	*Companion*, 9 mag., 18″·3; *vis.* with a 2 in. refractor.
Gamma Andromedæ	2	01·7	+42	09	Fine double; companion 5 mag., 9″·7, 061°.
H.VI 33–4 Persei	2	18·3	+56	59	Double cluster; Sword-handle.
Omicron Ceti	2	17·5	− 3	08	*Mira.* Max. may be mag. 2 to 4; min. mag. 9.
Iota Cassiopeiæ	2	26·1	+67	15	Triple; mags. 4½, 7, 8; dists. 2½″, 7½″.
Rho Persei	3	02·9	+38	42	Reddish irreg. variable; mag. 3½ to 4.
Beta Persei	3	05·8	+40	49	*Algol;* eclipsing binary, mag. 2¼–3½.
Eta Tauri	3	45·3	+24	00	*Alcyone;* leader of the Pleiades.
Alpha Tauri	4	33·9	+16	26	*Aldebaran;* fine red star. In Hyades.
Kappa Leporis	5	11·6	−12	59	Double. Mags. 5, 7; yellowish, blue.
Beta Orionis	5	12·8	− 8	15	*Rigel.* 7 mag. companion at 9½″.
Alpha Aurigæ	5	14·0	+45	58	*Capella.* Superb yellow star; spectrum G.
Delta Orionis	5	30·2	− 0	19	Upper star of Orion's Belt. 7 mag. companion at 52″·8; easy object.
M1 Tauri	5	32·3	+22	00	Crab Nebula, near Zeta Tauri.
M42 Orionis	5	33·4	− 5	24	Great Nebula in Orion. Contains the Trapezium, Theta Orionis.
Iota Orionis	5	33·7	+ 5	56	Double star; mags. 3½, 7½; dist. 11″·4. Lowest star of Orion's Sword.
Sigma Orionis	5	36·9	− 2	37	Multiple in Orion's Sword. Mags. 4, 10, 7½, 7.
Zeta Orionis	5	38·9	− 1	58	Companion, 5 mag., 2″·8. Test for 2 in. OG.
Alpha Orionis	5	53·2	+ 7	24	*Betelgeux.* Superb M-type orange star.
M35 Geminorum	6	06·5	+24	21	Good open cluster nr. Eta, Mu Geminorum.
Eta Geminorum	6	12·7	+22	31	Var. 3·3–4·2; period 231 d. Orange.
Beta Monocerotis	6	27·1	− 7	00	Triple; mags. 5, 5½, 6; dists. 7″·4, 2″·8.
H.VII 2 Monocerotis	6	30·7	+ 4	53	Open cluster, just visible to naked eye.
Alpha Canis Majoris	6	43·6	−16	40	*Sirius.* Fine sight in binoculars.
M41 Canis Majoris	6	45·5	−20	42	Open cluster, just visible to naked eye.
Zeta Geminorum	7	02·0	+20	38	Cepheid; mag. 3·7–4·3; 10·2 d. Type G.
Alpha Geminorum	7	32·3	+31	58	*Castor.* Fine binary, but now too close to be well seen with small telescopes.
Beta Geminorum	7	43·1	+28	07	*Pollux.* Orange; compare with *Castor.*
M44 Cancri	8	38	+20	07	*Præsepe.* Open cluster nr. Delta Cancri.
Alpha Hydræ	9	25·8	− 8	30	*Alphard.* Type K; fine orange star.
Gamma Leonis	10	18·0	+20	01	Binary; mags. 2·4, 3·8. Orange primary.
U Hydræ	10	35·8	−13	12	Mag. 4½ to 6; N-type, irreg. var. Red.
M97 Ursæ Majoris	11	12·6	+55	13	Owl Nebula; diam. 3′. Planetary.
Gamma Virginis	12	39·8	− 1	15	Fine binary; components equal, mag. 3½.
Alpha Canum Venat.	12	54·3	+38	31	*Cor Caroli.* Easy double; mags. 3, 5½:20″.
Zeta Ursæ Majoris	13	22·5	+55	07	*Mizar.* Binary; mags. 2½, 4½; 14½″. Forms a naked-eye double with *Alcor.*
M3 Canum Venaticorum	13	40·6	+28	34	Bright globular.
Alpha Boötis	14	14·0	+19	22	*Arcturus.* Magnificent orange star.
Epsilon Boötis	14	43·4	+27	14	Double; mags 3, 6; 2″·8. Yellow, bluish.
R Coronæ Borealis	15	47·1	+28	15	Irregular var; max. mag. 6. min. 12.
T Coronæ Borealis	15	58·0	+26	01	Recurrent nova; usually below mag. 8.
Beta Scorpionis	16	03·3	−19	42	Easy double; mags. 3, 5½; dist. 14″.
M80 Scorpionis	16	14·9	−22	53	Globular; between *Antares*, Beta Scorpionis.
M4 Scorpionis	16	21·5	−26	26	Open cluster close to *Antares.*
Eta Draconis	16	23·5	+61	36	Double; mags. 3, 8; 6″. Test for 3 in. O.G.

Object	R.A. *h*	*m*	Dec. °	′	*Remarks*
Alpha Scorpionis	16	27·2	−26	21	*Antares.* 7 mag. green companion at 3″.
Zeta Herculis	16	39·9	+31	40	Binary; mags. 3, 6¼. Period 34 years.
M13 Herculis	16	40	+36	31	Brightest globular visible in England.
Alpha Herculis	17	13·0	+14	26	Red variable; mag. 3¼–3¾. There is a 6 mag. green companion at 4½″.
M92 Herculis	17	16·1	+43	11	Globular between Eta and Iota Herculis.
M7 Scorpionis	17	51·6	−34	48	Fine open cluster; very low in England.
M23 Sagittarii	17	54·8	−19	01	Open cluster nearly 50′ in diameter.
H.VI 37 Draconis	17	58·6	+66	38	Bright planetary.
M8 Sagittarii	18	01·4	−24	23	Lagoon Nebula; gaseous. Just visible with naked eye. Very rich area.
N.G.C. 6572 Ophiuchi	18	10·9	+ 6	50	Bright planetary, between Beta Ophiuchi and Zeta Aquilæ.
M17 Sagittarii	18	18·8	−16	12	Omega Nebula. Gaseous; large and bright.
Alpha Lyræ	18	35·7	+38	45	*Vega.* Glorious bluish star. Type A.
Epsilon Lyræ	18	43·2	+39	34	Quadruple; 4 stars vis. with a 3 in. O.G.
Zeta Lyræ	18	43·5	+37	34	Easy double. Mags. 4¼, 5½; distance 44″.
Beta Lyræ	18	48·8	+33	19	Eclipsing binary; mag. 3·4–4·1; 12·9 d.
M11 Scuti	18	49·0	− 6	19	Wild Duck; bright open cluster.
M57 Lyræ	18	52·6	+32	59	Ring Nebula; brightest of planetaries.
Theta Serpentis	18	54·4	+ 4	09	Wide, easy double; mags. 4, 4; 22″·3.
Beta Cygni	19	29·3	+27	53	*Albireo.* Most beautiful of all doubles; mags. 3, 5¼: 35″. Very easy. Orange, blue, or green.
Chi Cygni	19	49·2	+32	49	M-type variable; mag. 4 to 14; 409 days.
Eta Aquilæ	19	50·6	+ 0	55	Cepheid. Mag. 3·7–4·5; 7·18 days.
M27 Vulpeculæ	19	58·1	+22	37	Dumb-bell Nebula, near Gamma Sagittæ.
Alpha Capricorni	20	15·8	−12	39	Naked-eye double; mags. 3, 7, 4·3; 378″.
Alpha Cygni	20	40·2	+45	09	*Deneb.* Fine star of spectrum A2 (pec.).
Gamma Delphini	20	45·0	+16	00	Easy double; 4, 5; dist. 10½″. Yellowish, bluish.
H.IV 1 Aquarii	21	02·1	−11	31	Bright planetary near Nu Aquarii.
61 Cygni	21	05·3	+38	34	Binary; 5·3, 5·9; dist. 25″.
M15 Pegasi	21	28·3	+12	01	Bright globular, near Epsilon Pegasi.
Beta Cephei	21	28·2	+70	24	Double; mags. 3, 8; 13″·7. Easy test.
M39 Cygni	21	31·0	+48	17	Open cluster between *Deneb* and Alpha Lacertæ. Well seen with low powers.
Mu Cephei	21	42·4	+58	36	'Garnet Star'; var. mags. 4–6. Very red.
Delta Cephei	22	27·8	+58	14	Prototype Cepheid; mag. 3·7–4·3; 5·37 d.
Beta Pegasi	23	02·0	+27	53	Betelgeux type irregular variable, mag. 2¼–2¾; orange. In Square of Pegasus.

A Cycle of Clusters and Nebulæ

JAMES MUIRDEN

It is a great pity that astronomical articles nearly always emphasize the importance of devoting a small telescope to serious observation, at the expense of simple pleasure. For an astronomer to be worthy of the name, he must balance the known against the unknown; and while the observation of double stars, star clusters and nebulæ is not scientifically useful, in the sense that there is no chance of making a discovery of any sort, it would be wrong to dismiss this pastime as superfluous. The heavens contain a great deal of excitement for anyone who is content simply to let his telescope wander among the night-sky regions and come to rest on objects of beauty, and a few evenings spent identifying some of the objects mentioned in this article will compile a small mental reference-library of stellar showpieces. Double stars are catered for in many lists; I here confine myself to the more prominent star clusters and a few bright nebulæ. They are all indicated on the maps, and, of course, *Norton's Star Atlas* includes these and many more in its pages.

For the sake of convenience I have divided up the sky into an approximate seasonal sequence.

SPRING

The distinctive feature of the spring sky is the presence of Ursa Major, the Great Bear, in the zenith; and this contains three nebulæ of great interest, all mentioned in Messier's catalogue of 1784 and therefore identified by the letter M; they are marked on Map I. Easily found by projecting a line from Gamma through Alpha and prolonged for just over the distance are M81 and M82, two bright nebulæ that can just be included together in a low-

power field. They are actually external spiral galaxies, resembling our own, and M82 appears as a curved streak because we are seeing it roughly edge-on. The third feature, M97, near Beta, is popularly known as the Owl Nebula from its owlish appearance in long-exposure photographs. A small telescope will show it as a faint patch of light.

M97 is a true nebula, a glowing patch of gas inside the Galaxy, and another galactic feature is to be found in the nearby constellation of Canes Venatici (Map II), below the curve formed by the handle of the Bear. This is M3, a globular cluster containing tens of thousands of stars, but so far away that a small telescope shows it as just a blur of light. It is found half-way along a line joining *Arcturus* (Alpha Boötis) with *Cor Caroli* (Alpha Canum Venaticorum).

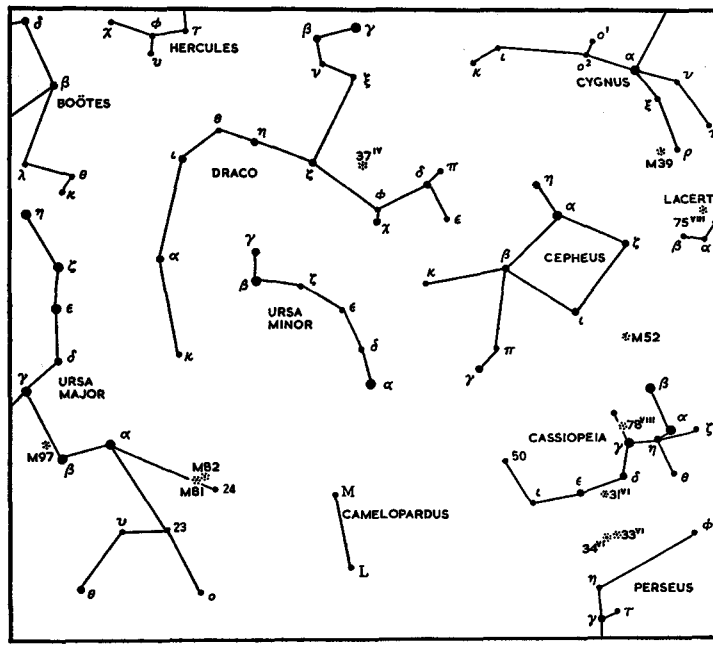
South of Canes Venatici are the neighbouring constellations of Coma Berenices and Virgo, in which are clustered hundreds of faint galaxies. Only one, however, is bright enough to be interesting in a small telescope; this is M64, in Coma (Map II), about a third of the way from Alpha to Gamma. There is also a globular cluster, M53, very easily found just north of Alpha, but rather faint in a small instrument.

Leo (Map II) contains its own crop of galaxies, and M65 and M66, very close together between Iota and Theta, are bright enough to be worth sweeping up.

SUMMER

The key to the summer sky is the brilliant star *Vega* (Alpha Lyræ); and Lyra (Map III) contains one of the most interesting nebular objects in the sky. Turn the telescope to a point midway between Beta and Gamma, and a low-power eyepiece will reveal what looks like a small luminous smoke-ring; once it is found, a higher magnification will make its annular form more obvious. This is the Ring Nebula, M57, and large telescopes reveal a faint star at its centre, presumably the source of its generation many millions of years ago.

Adjoining Lyra to the west is Hercules (Map III), and this



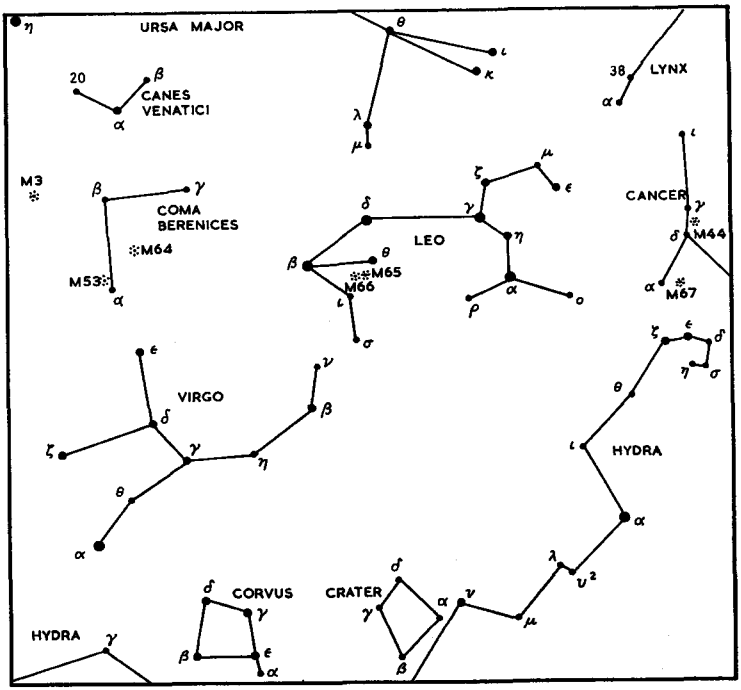
Map I

contains the most famous globular cluster visible in the northern hemisphere – M13, easily swept up between Eta and Zeta. M13 is large and bright, but even so it takes an 8-inch telescope to begin to show individual stars. I have a personal preference for the other bright globular in Hercules – M92, lying between Eta and Iota. This is smaller than M13, but shows a more pronounced nucleus. With a large telescope, however, its giant brother is a superb sight.

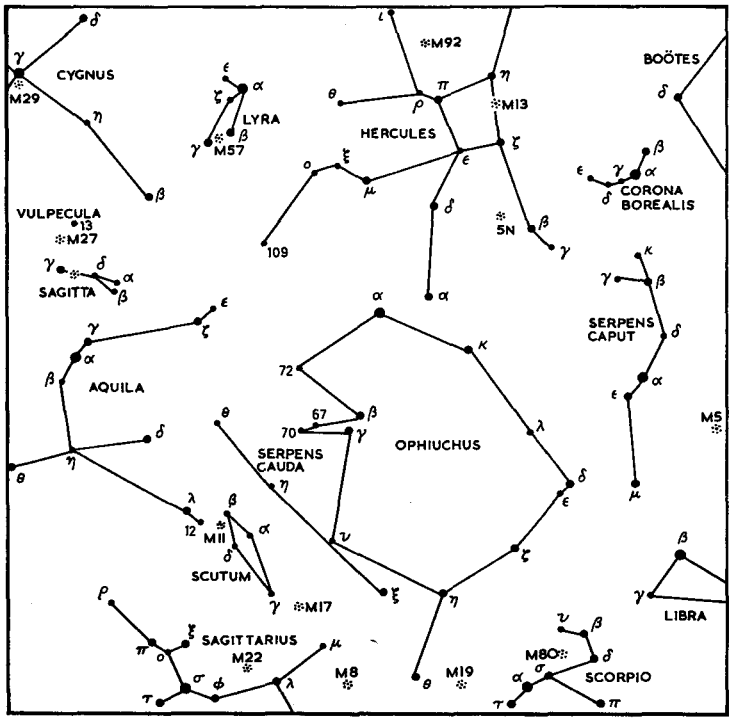
Hercules also contains a small planetary nebula (so called because its disk rather resembles that of a planet); this is Σ5N, forming an approximate equilateral triangle with Delta and Zeta. North of Hercules, in Draco (Map I) we find another planetary: H.IV 37, as classed in Sir William Herschel's catalogue, completed in 1822. This is so bright that it is easily found between

Delta and Zeta. Serpens (Map III), to the west, has a fine globular cluster in M5, which would be hard to find were it not for the fifth-magnitude star to the south-east.

To the west of Lyra is Cygnus (Map IV), the Northern Cross, a constellation lying in a rich part of the Milky Way and therefore worth sweeping at random. It is, however, strangely lacking in telescopic clusters, the most noteworthy being M39, near Pi^2, and the coarse group M29, two degrees south of Gamma. South, in the obscure group Vulpecula (Map III), lies the Dumb-bell Nebula, M27. A small telescope shows it as two misty patches of light about 3 degrees north of Gamma Sagittæ; long-exposure photography reveals the two patches as nothing more than the brightest



Map II



Map III

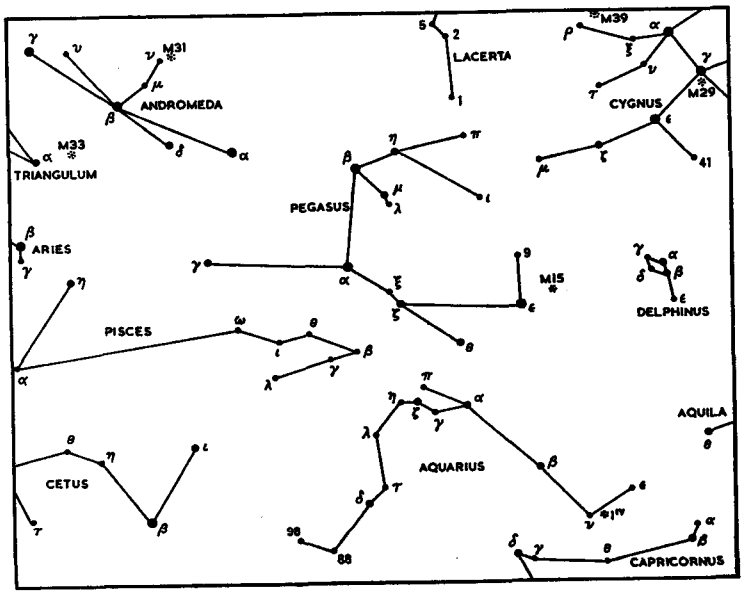
regions of a complete disk. Sagitta itself contains M71, a rather faint globular cluster between Gamma and Delta.

Sweeping down towards the southern summer horizon brings us to perhaps the most remarkable region of the sky: the neighbourhood of Sagittarius (Map III), which is filled with globular clusters and nebulæ of every description; this is because we are now looking towards the very nucleus of the Galaxy, and the star-fields are superb. It is therefore doubly unfortunate that Sagittarius is so low in British skies. Of the many that are presented for inspection, perhaps the finest nebulæ are the Lagoon Nebula (M8) and the Horseshoe Nebula (M17), arranged on either side of Mu,

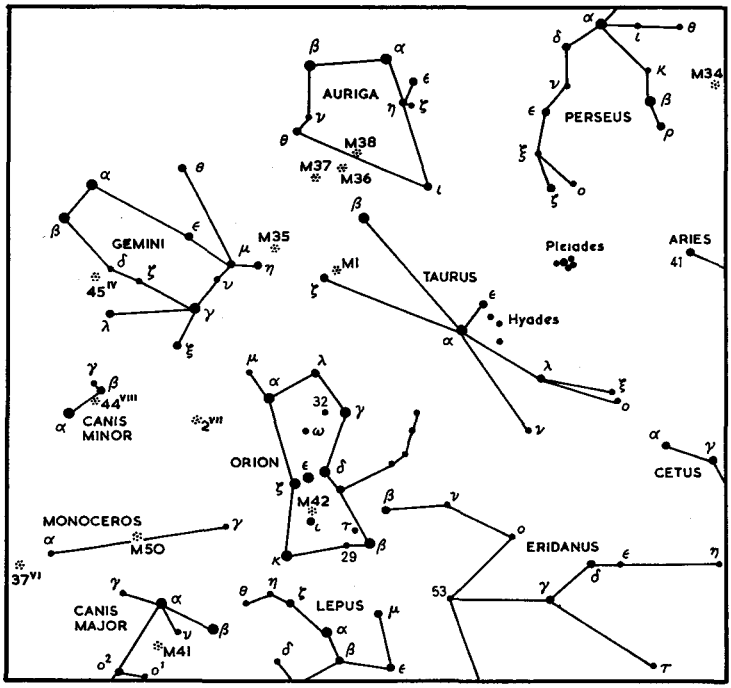
while M22, near Lambda, is a large bright globular cluster; M8, too, is followed by a cluster. Sweeping to Scorpio (Map III), we find a much more condensed cluster in M80, half-way between Alpha (*Antares*) and Beta, while the curious triangular cluster M11 lies just north of Sagittarius, in Scutum (Map III), a little way south-east of Beta. Mention should also be made of M19, in Ophiuchus (Map III), on a line joining Theta Ophiuchi and Tau Scorpii. On a transparent summer night no time should be lost in sweeping over this wonderful but elusive region.

AUTUMN

One of the brightest reaches of the Milky Way, as seen to northern observers, lies in Cassiopeia and Perseus, and is overhead in the autumn. A telescope swept across Perseus (Maps I and V) will reveal some magnificent fields, and never more so than when



Map IV



Map V

pointed roughly half-way between Gamma Persei and Delta Cassiopeiæ, at the stellar showpiece of the northern heavens – the Perseus Double Cluster. Two open clusters, each larger than the Full Moon, lie side by side against the sky, and on a transparent night the very background is granular with half-revealed stars. Herschel identified them as H.VI 33 and 34, and they are easily seen with the naked eye. Another cluster in Perseus, M34, is a coarse bright one between *Algol* (Beta Persei) and Gamma Andromedæ.

The distinctive constellation Cassiopeia (Map I), also boasts two bright open clusters: M52 (continue a line from Alpha through Beta for slightly more than the same distance), and H.VI 31,

south of the line joining Delta and Epsilon. Another fine open cluster, H.VIII 78, is easily found between Gamma and Kappa. Yet another specimen of the same type lies in Lacerta (Maps I and IV), between Cassiopeia and Cygnus, in the Lizard's head. This is H.VIII 75, a little preceding the prominent diamond of four bright stars.

South of this region lies a very prominent feature: the Great Square of Pegasus, a landmark of the autumn sky. Pegasus (Map IV), as a constellation, is rather uninteresing; but it does contain one noteworthy object, the bright globular cluster M15, 5 degrees north-west of Epsilon. There is a bright planetary nebula in this region, too, in Aquarius (Map IV): H.IV 1, whose outline when seen in long-exposure photographs has earned it the nickname 'the Saturn Nebula'. A small telescope will pick it up preceding Nu by a degree or so, but a large instrument is necessary to begin to reveal its true form.

If we now look upwards towards the zenith, we find the most famous nebular object in the sky. This is the Andromeda Galaxy (Map IV), M31, one of the Galaxy's near neighbours in space. Once again it requires the photographic plate to pick out its true outline – a vast catherine-wheel of stars – but it is bright enough to be easily visible with the unaided eye. Find the middle star in Andromeda's line (Beta); north-west of that is Mu, north-west again, Nu; and north-west of Nu is M31. A small telescope shows it as an extensive misty patch, and it will also show the two satellite galaxies – equivalents of the Magellanic Clouds in our own system – as two dimmer objects on either side of the main mass. A very curious feature of the galaxy is its almost star-like nucleus.

On the opposite side of Beta Andromedæ is another close galaxy, M33, in Triangulum (Map IV) – but this is a very different matter. Its angular dimensions are almost as great as those of M31, but it is so dim as to be one of the most elusive of all telescopic objects. The first essential is a very clear, moonless night; the second, a low magnification, since a powerful eyepiece will make it invisible from sheer lack of contrast.

WINTER

When it performs in traditional vein, winter gives us nights of frosty clarity; and it is under these conditions that the observer should search in Taurus (Map V), marked by its gleaming orange leader *Aldebaran*, for a faint spot of light just north of Zeta. This is M1, the Crab Nebula, which although unspectacular in a small telescope is really one of the most dramatic objects known to astronomers. Nine centuries ago, in the year 1054, Chinese astronomers observed a brilliant star flare out in the position now marked by M1. It was a supernova – a star that suddenly explodes in a titanic blast of energy – and the nebula that we see today is simply the remains of its material.

Taurus also provides two more spectacular objects, the star-clusters of the Hyades (around *Aldebaran*) and the Pleiades, which are, of course, very obvious. Both these clusters are relatively close to the Sun (about 130 and 400 light-years respectively), which is why they appear so bright and widespread; on the galactic scale they are actually rather unimportant. The Pleiades, also known as the Seven Sisters for the simple reason that the unaided eye can usually see seven stars, form a useful test of vision, and a telescope will show several double stars in the group.

Leaving Taurus for the neighbouring constellation of Auriga (Map V) brings us to three fine open clusters occupying the region between Theta Aurigæ and Beta Tauri: M37, M36 and M38 in order from east to west. M38, which lies on the edge of the Milky Way, has the rough arrangement of a cross, but M37 is the most densely packed, numbering hundreds of faint stars within its confines. Gemini (Map V), to the west, is clearly marked by the bright stars Alpha (*Castor*) and Beta (*Pollux*), and contains some telescopic objects: M35, between Epsilon Geminorum and Zeta Tauri, a large cluster of faint stars, and a planetary nebula, H.IV 45, near Delta, which looks rather like a star surrounded by haze, as though there were dew on the eyepiece.

Cancer (Map II), in the region to the west of Gemini, is an

obscure constellation containing a remarkable bright cluster, M44. Known as Præsepe, or the Beehive, it is a widespread swarm of stars visible with the naked eye and filling a telescope's low-power field, situated roughly between Gamma and Delta (binoculars show it well). There is also a fainter cluster, M67, west of Alpha.

Canis Minor (Map V) contains an open cluster, H.VIII 44, south of Beta; but its larger brother, Canis Major (Map V), exhibits a much more remarkable specimen, M41, in which the brighter stars are arrayed in a splendid curved effect. Led by *Sirius*, the brightest star in the sky, Canis Major is an impressive constellation, and it is a pity that it must always be confined to such a low altitude; under good conditions, however, M41 is visible with the naked eye a few degrees south of Sirius. The neighbouring constellation, Monoceros (Map V), which lies in a rich part of the Milky Way, contains three more open clusters well worth looking up: H.VII 2, on a line joining *Procyon* (Alpha Canis Minoris) and *Betelgeux* (Alpha Orionis), whose members are arrayed around a sixth-magnitude yellow star; H.VI 37, east of Alpha, a large cluster of faint stars; and M50, a beautiful bright cluster lying a third of the way from *Sirius* to *Procyon*. This part of the Milky Way is so dense that simple sweeping will pick up many glorious sights.

Finally, at the core of the winter sky, we come to Orion; and there is surely no need to offer a guide to its nebula, the brightest in the sky, a few degrees south of the central star in the belt. Designated M42, but better known as the Great Nebula in Orion, it is clearly visible with the naked eye and is amplified by the telescope into a sea-green stratum of light, with the four bright stars of the Trapezium (Theta Orionis) shining at its centre. This portion is actually only the nucleus of a colossal region of gas that occupies most of the constellation; it is far too tenuous to be detectable other than by photography, although a glance at the star Iota, a double star, shows a distinct glow that is actually a local condensation of the Great Nebula.

This fine object, then, completes the cycle. Demands of space

have had necessarily to limit my selection, but anyone hungry for more deep-space wonders will find them listed by the score in Webb's classic *Celestial Objects for Common Telescopes*, and most of them marked on *Norton's Star Atlas*. I hope that the reader will feel tempted to follow them up.

PART FOUR

Astronomical Societies

The advantages of joining an astronomical society are obvious enough. In previous *Yearbooks* tabulated information about the various societies was given, but there have been requests for something more detailed; accordingly, the various presidents, secretaries and other officials have contributed fuller notes.

The leading section, concerning the British Astronomical Association, has been written by E. A. Beet, President for 1962–4. The Royal Astronomical Society (Burlington House, Piccadilly, London W.1) has not been included here, since it is, of course, a professional organization with only a sprinkling of amateurs.

It is possible that the list of societies may not be quite complete. If any have been omitted, the secretaries concerned are invited to write to the Editor (c/o Messrs Eyre & Spottiswoode, 22 Henrietta Street, Strand, London W.C.2) so that the relevant notes may be included in the 1966 *Yearbook*. – *Editor.*

THE BRITISH ASTRONOMICAL ASSOCIATION

By E. A. Beet, *President 1962–64*

The Association was founded in 1890 to bring together amateurs interested in astronomy, 'especially possessors of minor equipment', for mutual help. It cannot be said to have an individual founder, but of the considerable group responsible for bringing it into being one name stands out: E. W. Maunder, FRAS, was the man from whom executive action largely came. Numbers grew quickly and for most of the first 50 years was a little under a thousand. It is now about 2,600.

Meetings are held in London on the last Wednesday in the month, except in July, August and September, usually at 5 p.m. For the first few years the BAA had no permanent base. From

1897 to 1942 it met at Sion College on the Thames Embankment, where in addition to the borrowed meeting-hall there was a room in which the growing library could be housed. Since 1942 the Association has enjoyed the hospitality of the Royal Astronomical Society at Burlington House, Piccadilly, using their meeting-room and again having its own library. This arrangement is a happy one, for here is the very heart of British astronomy. The amateurs gather in the room used by the experts and their distinguished guests from other countries; from the walls look down the portraits of the great ones with, one would like to feel, approval and encouragement; the President is humbled if he thinks of those who in the past have occupied the chair in which he sits. Numbers have more than doubled since 1942 and from time to time it is suggested that a move to a larger hall is called for, but a little congestion is not too high a price to pay for the tradition and atmosphere which Burlington House affords.

The Library in Burlington House, where there is a good collection of books, periodicals, maps and such-like, is open from 1 to 7 p.m. on Wednesdays throughout the year (except for a short holiday period in August), and the Librarian or his assistant is in attendance. Provincial members can buy a catalogue and borrow books by post. The Library also houses the large collection of lantern slides available for hire; the bulk of these are in the old standard size, $3\frac{1}{4} \times 3\frac{1}{4}$ inches, but there is a growing collection of the miniature 2×2 slides as well.

While discussing material mention must be made of the 200 or so instruments available for loan to members. Telescopes range from the simplest for beginners to quite large equatorials for experts; there is also equipment for radio astronomy, and calculating machines for computers. The better instruments, naturally enough, are reserved for those doing serious work approved by the Council.

It was the intention of the founders to form branches in the provinces and overseas, and a number have existed from time to time. Now there is only one, in Australia, but on the other hand some 140 schools and local societies are affiliated. This gives a link with the Association without any loss of local independence

and seems to meet adequately local needs. In recent years a September meeting has been held at the headquarters of an affiliated society, and so far Coventry, Bristol, Leicester and Leeds have been successfully visited in this way. Another recent innovation has been an annual week-end course in astronomy held at some residential college of adult education.

The Association is open to all who are interested in astronomy, and many such people are not practical observers. Nevertheless 'the association of observers' is an established tradition which is still strong after 70 changing years. It is not easy for a lone amateur to make a serious contribution to science, and it was hoped by the founders that if observers of like interests could be brought together, to work co-operatively and pool their results, something of scientific value would emerge. It did, and it still does, though on a rather smaller scale as techniques become increasingly professional in nature. A few fields are still left to a significant degree in amateur hands, such as some variable stars and the surfaces of the planets – to mention only two. The bulk of the observing work is done through the Observing Sections, of which there are fifteen: the Sun, the Moon, Mercury and Venus, Mars, Jupiter, Saturn, Comets, the Aurora, Variable Stars, Instruments and Observing Methods, Computing, Historical, Radio and Electronics, and Artificial Satellites. Many of these have existed from the beginning, but the last two are obviously of recent origin. The function of the Section is twofold. The first is to establish communication, through its experienced Director, between members of like interest, in order that they may mutually assist one another by sharing ideas and experience. The second, where the leadership of the Director is specially important, is to exploit whenever possible opportunities of co-operative work which may lead to a contribution to science. From time to time, and usually not less than once a year, a report on the work of each section is published.

The main publication is the *Journal*, which is issued eight times a year. It contains accounts of the meetings, reports on the work of the sections, papers contributed by members, notes on current astronomy, and book reviews. Needless to say, it also contains

domestic news and announcements, for it is the only regular link between the Council and most of the world-wide membership. It is difficult for the editor to make every issue of a moderately sized magazine interesting to all members, but over the year there is something for everybody, beginner and expert. The second regular publication is the annual *Handbook*, containing all the day-to-day information needed by the amateur astronomer. Its use is not confined to amateurs, however, as it is the medium of publication for the Commonwealth of occultation predictions, as these are no longer included in the *Astronomical Ephemeris* (successor to the *Nautical Almanac*). The comet predictions are also of special value. Other publications appear from time to time. Recent major examples have been *Memoirs* on the Jupiter Section, Earth Satellites, Radio Astronomy and Cometary Orbits, this last being produced by arrangement with the International Astronomical Union. Among the minor publications should be mentioned *The BAA; its Nature, Aims and Methods*. This is a guide to observing methods and an account of the section organization; it is issued automatically to new members and is also available for sale to anyone.

When a comet is discovered, or some other event occurs unexpectedly, observations are wanted at once from active observers, and in any case the opportunity for observation may be very brief. To meet this kind of emergency the BAA issues *Circulars*, produced when wanted and at very short notice. These are distributed by post to those who have paid a small extra subscription to cover their cost and their wide circulation can be taken as proof of their value.

By reason of its size and services the British Astronomical Association may reasonably be regarded as the leading amateur astronomical society in the United Kingdom, though it is not the oldest, nor is it the only one with national coverage. The leading founder was a professional, and throughout its history such have taken their places with amateurs as officers, council and ordinary members; the Association owes much to their help and encouragement.

The British Astronomical Association, 303 Bath Road, Hounslow West, Middlesex. All inquiries to the Assistant Secretary at the above address, by post only, please. Annual subscription, including the *Journal* and the *Handbook*, 45*s*.

THE JUNIOR ASTRONOMICAL SOCIETY

The JAS was founded to promote and encourage an interest in amateur astronomy, the primary aim being to help the beginner in the subject. (The word 'junior' in the title signifies junior in knowledge rather than age.) However, the scope of the available knowledge and advice is designed to cover the needs of all members from the raw recruit to the much more advanced student.

The main publication of the Society is the journal *Hermes*, which is published four times a year and contains a series of regular articles on popular topics, many of an instructional nature. There is a quarterly Sky Diary, together with a selection of papers, often by well-known astronomers, covering a wide variety of subjects.

The JAS has also established observing sections covering studies of the Moon, planets, variable stars and other main aspects of practical astronomy. The section directors are always willing to give advice on the techniques of observing, and members are encouraged to take part in the planned programmes of observation. An inquiry panel is available to answer members' queries on subjects such as the purchase and construction of instruments, and to advise about books. The Society maintains a library service, but it is intended mainly for country members and those to whom the public library service is not readily available.

Various local groups throughout the country are affiliated to the Society, and JAS members are encouraged, where possible, to organize discussion and observing groups within their own areas.

Meetings are held four times a year at Caxton Hall, Westminster, London.

The Society is under the patronage of Dr J. G. Porter, BSC, FRAS and is run by an elected President and Council. All inquiries

should be sent to the Secretary: E. W. Turner, 44 Cedar Way, Basingstoke, Hampshire. – *R. Atwell.*

THE AYLESBURY ASTRONOMICAL SOCIETY

W.E.A. lectures by Mr Colin Hunt, under the auspices of Oxford University, Extra-Mural Studies, were responsible for the formation of this Society. In the 2 years which have elapsed since then the Society has grown to some 40 members; its President is Mr Hunt, with two vice-presidents, a council and a combined office of secretary-treasurer.

Optical and radio-astronomy programmes are being prepared; visits to Herstmonceux, London University, and Frank Hyde's radio-astronomy observatory at Clacton have been made, and the Society has become affiliated to the BAA. There are two sections, senior and junior. Various instruments are at the Society's disposal, notably the President's 12-inch reflector. All inquiries should be sent to Norman Neale, 9 Elm Close, Butler's Cross, Aylesbury, Buckinghamshire. – *Norman Neale.*

THE BIRMINGHAM ASTRONOMY GROUP

The Group, formed in 1950, is associated with the Department of Extra-Mural Studies of the University of Birmingham, and is affiliated to the BAA. It is also one of the several societies affiliated to the Birmingham and Midland Institute, where its meetings are held.

It encourages astronomical activities in several directions, observation and construction being prominent. General meetings, with lectures and film-shows, take place monthly from October to May. The Construction Section meets weekly in its own workroom, and the Observation and Junior Sections meet monthly. A small library is maintained for the use of members. Other forms of activity are being planned.

The Group has the use of the 12-inch reflector belonging to the Midland Institute, and has under construction a 21-inch reflector, which, when installed, will permit great extension of the programme of observational work.

Membership is open to anyone interested in astronomy. The annual subscription is 10*s* (5*s* for junior members under 21). All inquiries should be sent to W. E. Marsh, 17 Hannafore Road, Edgbaston, Birmingham 16. – *W. E. Marsh.*

THE BRISTOL ASTRONOMICAL SOCIETY

The Bristol Astronomical Society, affiliated to the BAA has had an active life of over 25 years and now numbers nearly 50.

The monthly meetings are held on the third Friday of each month, September to May, in the Lecture Theatre of Bristol University. Normally they start at 7 p.m. with a discussion of members' observations and topical astronomical matter, and a ten-minute instructional talk. Then follows the main talk by a member or visiting speaker.

Members' instruments range from small refractors to 12-inch reflectors. A fair amount of observation is done under the guidance of a Director of Observations, mainly of the Moon and planets, while several members are devotees of variable stars, and in addition regularly observe any current novæ. Astronomical photography, particularly of comets, interests some members, and a start is soon to be made on photoelectric work.

All inquiries should be sent to S. J. Williams, 12 Lambley Road, Bristol 5. – *S. J. Williams.*

THE CAITHNESS AND DOUNREAY ASTRONOMICAL SOCIETY

The Caithness and Dounreay Astronomical Society was founded in 1963, and holds fortnightly meetings. The Chairman is A. J. Oliphant, 17 Rockwell Crescent, Thurso; the Secretary-Treasurer, to whom all inquiries should be addressed, is Miss Margarete Jackson A. Clark, Room 31, Ormlie Lodge, Thurso. – *R. Knox.*

THE CAMBRIAN ASTRONOMICAL SOCIETY

The Cambrian Astronomical Society was formed in 1963 by the amalgamation of the Cardiff Astronomical Society and the South

Wales Astronomical Society. The annual subscription is 15*s*; for a member receiving the old age pension, or who is aged less than 16, the subscription is 7*s* 6*d*. Fortnightly meetings are held in Cardiff, at 7.30 p.m. on Friday evenings, October to June inclusive. A monthly Bulletin is issued. The Secretaries are R. W. Skelly and W. H. Sutherland; all inquiries should be addressed to 57 Park Avenue, Whitchurch, Cardiff.

THE CAMBRIDGE ASTRONOMICAL ASSOCIATION

The Society was founded 4 years ago. Membership is open to all those who are interested in astronomy and are over 15 years of age; the entrance fee is 2*s* 6*d*, and the annual subscription 21*s*, with a subscription of 7*s* 6*d* for those under 18 years of age, or full-time students. Members have the advantage of being able to visit the Cambridge observatories on the public days once a month. Plans are being made to build a Society telescope; meanwhile, a member has loaned his 6-inch reflector for the Society's use.

The Society meets at 7 Brooklands Avenue, Cambridge, on the second Monday of each month from October to July, at 8 p.m. The Secretary is S. R. Whistler, 5 Haggis Gap, Fulbourn. – *R. W. Potts.*

DEPARTMENT OF ASTRONOMY, CHESTER SOCIETY OF NATURAL SCIENCE, LITERATURE AND ART

Meetings are held twice a month during the session. The main meeting is held in the Grosvenor Museum, Grosvenor Road, Chester, at which lectures and talks are given from September to December inclusive. From January to May a course of lectures is held in conjunction with the Liverpool University Extra-mural Department.

THE CHESTERFIELD ASTRONOMICAL SOCIETY

Headquarters: The Barnett Observatory, Newbold, Chesterfield. The Society was formed in 1956 to promote the building of an

observatory and telescope in Chesterfield, and to promote astronomical interest in the town. This project was completed in 1961, and the Society now owns an 18-inch Newtonian reflector, housed in a conventional observatory with an aluminium dome. Adjoining the observatory and connected by a corridor is a lecture-room capable of seating 40 persons. Membership is not restricted; the adult subscription is 15*s* per annum with an entrance fee of £2 2*s*. For juniors the subscriptions are less and there is no entry fee. Lecture meetings are held at various times throughout the year, and there is an informal meeting every Friday evening. New members must first become 'qualified' to use the telescope, after which they may pursue their own lines of observation; but the Society does inaugurate programmes, and has for the past two years run a programme specifically concerned with the planet Jupiter. All inquiries should be sent to Mrs M. E. Garrod, 10 George Street, Brimington, Chesterfield. – *M. E. Garrod.*

THE CRAWLEY ASTRONOMICAL SOCIETY

The Society, founded in 1964, has its headquarters at the Crawley College of Further Education, Crawley, Sussex. The President is Major-General C. Lloyd, CBE; the Chairman, to whom all inquiries should be sent, is F. D. Cooper, BSC. The annual subscription is 7*s* 6*d*. Meetings are held monthly at Crawley College, and the club-room is open during the week for observers' meetings. The Society plans to build an 8½-inch reflector, and also a radio telescope; to take part in various observing programmes in association with the BAA, and to encourage an interest in astronomy and provide a social centre for amateurs in the Crawley area. – *Pamela Pyer.*

THE CRAYFORD MANOR HOUSE ASTRONOMICAL SOCIETY

The Society, based at the Manor House Centre, was formed in November 1961 from members of the classes being run at the Centre under the tutorship of G. E. Taylor, FRAS.

The Society, which is affiliated to the BAA, holds meetings

once a month during term-time. There is no Society fee, but there is a voluntary subscription of 6*d* per week for the purchase of astronomical journals. There are three observing sections; lunar and planetary, artificial satellites, and variable stars, each under a section director.

The H. P. Wilkins Memorial Observatory houses a 12-inch Newtonian reflector, with electric drive, constructed and maintained by the Observatory engineer, J. Wall. Other equipment includes a predictor telescope and a short-wave radio for time signals.

Observers, who have unlimited access to the instruments, are restricted to those who have passed a test of competence set by the Director, G. E. Taylor. Potential observers are given every encouragement to familiarize themselves with the equipment and to carry out regular programmes of work. The Warden of the Manor House Centre is L. L. Willcox, MA. All inquiries should be sent to R. H. Chambers, Manor House Centre, Crayford, Kent. – *R. H. Chambers.*

THE EASTBOURNE ASTRONOMICAL SOCIETY

The Society incorporates a group of the Junior Astronomical Society, and affiliated with it is the Astronomical Society of Eastbourne College. The Society was founded in 1960. Subscription: adults £1 1*s*, students 10*s* 6*d*. Apart from monthly meetings, often addressed by a visiting lecturer, a general course on astronomy is offered to members. A pass-mark in an annual examination, together with practical instruction in the use of telescopes, entitles a member to the use of the Society observatory without supervision. This observatory, sited on the top of Beachy Head, is a brick building given to the Society by Eastbourne Corporation. When alterations are completed it will have a rotatable dome and will house a specially designed 12-inch reflector. A large part of the cost has been donated by the Society's President, Gilbert S. Foyle, FRSA. All inquiries should be sent to W. O. Tutt, 80 Ringwood Road, Eastbourne, Sussex. – *W. O. Tutt.*

THE ASTRONOMICAL SOCIETY OF EDINBURGH

The Society was founded in 1924, but there had been two earlier astronomical societies. The first of these, the Edinburgh Astronomical Institution, was founded in 1811, took over the old Observatory on Calton Hill, and built the present Main Building of the Observatory.

The Observatory (which was for a period the Royal Observatory) has been run by the present Society for over 25 years. The main instruments at present are a 13-inch reflector, a 10-inch refractor, a 6-inch photovisual refractor, a 16 centimetre transit telescope, and various cameras. There are astronomical clocks, subsidiary instruments and a small radio telescope working at 80 mc/s.

Lecture meetings are held monthly throughout the year, and the Observatory is open to members every Friday evening. (It is in use for other purposes on the other nights.) There are various observing sections, and an instrument section. Monthly astronomical notes, with charts, are issued to members, and papers are published occasionally. The only Award made by the Society is that of the Lorimer Gold Medal. There is a good astronomical library, and collections of 3¼-inch and 2-inch slides.

There are about 100 members at present. Membership is open to all adults, the subscription being £1 per annum. Applicants must be nominated and recommended by a member. Further details may be had from the Secretary, N. G. Matthew, 126 West Savile Terrace, Edinburgh 9, Scotland. – *N. G. Matthew.*

THE FELLOWSHIP OF JUNIOR ASTRONOMERS, EDINBURGH

The Fellowship was founded in 1957 by N. G. Matthew, Director of the Calton Hill Observatory, and exists to encourage and assist young people in astronomical study and observation.

All interested, and between the ages of 12 and 18, are eligible for Associate membership. Admission as a Fellow is by written examination. Annual contribution, 7*s* 6*d*.

Meetings, with observing, are held on the second Saturday of

the month from September to June (7 p.m.) at the Calton Hill Observatory, near the city centre. Visitors are welcome. In addition, on one Sunday evening each month from September to March members meet at the Observatory for observations with the 6-inch photovisual refractor. Members are issued with log-books, and are encouraged to record all observations. The Fellowship owns some small telescopes, and these are ballotted for each month. There are also meetings of Sections on Friday evenings at the Observatory. Further information may be had from the Secretary, Miss Edith McLean, 58 Ogilvie Terrace, Edinburgh 11. – *N. G. Matthew.*

THE ASTRONOMICAL SOCIETY OF GLASGOW

The Society holds lectures on the third Thursday of each month, from September to April, in the Royal College of Science and Technology, Glasgow. It has an observing section for variable stars, and arranges visits to astronomical observatories; it publishes a monthly news-sheet. Assistance is available to members who wish to construct their own telescopes. The annual subscription is 10*s*. All inquiries should be sent to N. M. Orr, 164 Mugdock Road, Milngavie, Glasgow, Scotland. – *N. M. Orr.*

THE LEEDS ASTRONOMICAL SOCIETY

The Leeds Astronomical Society is open to all those interested in astronomy. It normally holds six meetings, plus the Annual General Meeting, each season, and arranges social events and visits from time to time. Meetings usually consist of lectures given by speakers invited from outside the Society. Members receive the Society's Occasional Notices, a magazine published four or five times a year, containing articles, reviews, reports of meetings, etc. They also receive regularly notes on current and forthcoming features of the night sky, and may borrow the Society's instruments and books free of charge. Membership increased from 68 to 124 in 1962–3, and extensions of the Society's activities are contemplated as a result of the expansion. Annual subscription:

10*s* (students 5*s*, members more than 10 miles from Leeds 5*s*, institutions £1). The Hon. Secretaries are B. L. Meek, Mathematics Department, The University, Leeds 2; and H. A. Newman, 29 Eleanor Drive, Harrogate. – *B. L. Meek.*

THE LEICESTER ASTRONOMICAL SOCIETY

The Society has been in existence for the past 12 years, its object being the encouragement of interest in astronomy and allied sciences. To achieve this, the Society meets monthly at the Leicester Museum and Art Gallery for lectures, films, etc., and holds observing nights for its members; it provides a library, and a panel of Officers to give guidance on telescope-making, observing and other topics. The Society also has a panel of speakers, in great demand in both the city and the county.

Visits to observatories and other places of interest are arranged, and it is the policy of the Society to have at least one 'outside' lecturer each year. Subscriptions, payable yearly, are 1 guinea (senior members), 12*s* 6*d* (intermediate members), 7*s* 6*d* (junior and student members). All inquiries should be sent to C. Shuttlewood, 49 Bringhurst Road, Leicester. – *C. Shuttlewood.*

THE LINCOLN ASTRONOMICAL SOCIETY

The Society was formed in June 1959, meetings being held at members' houses until numbers necessitated the hire of the YMCA Hall. Membership now stands at 90, and there is a very strong Junior Section.

A plot of land was bought, and the decision taken to build a lecture-room, workshop and observatory. Work began in 1960, and the lecture-hall, seating 100, was officially opened in September 1963. Mirror-grinding classes are held in the workshop, and the building of an observatory, in which it is planned to house a 20-inch reflector, is under way.

Meetings are held on the first Tuesday of each month throughout the year, with lectures covering all aspects of astronomy. An extensive library of magazines and books is available to members,

and a bi-monthly magazine, *Eyepiece*, is produced. The annual subscription is £1 for adults and 5*s* for juniors. The site of the lecture-room is off Westcliffe Street, Burton Road, Lincoln. All inquiries should be sent to P. Hammerton, 344 Brant Road, Lincoln. – *P. Hammerton.*

THE LIVERPOOL ASTRONOMICAL SOCIETY

The Liverpool Astronomical Society has a truly remarkable history, and may justly claim to be the father of popular amateur astronomy throughout the world. From it came the BAA, to which it was affiliated in 1925, and many overseas societies.

Founded in 1881 by the Rev. T. E. Espin, it published its monthly journal, and in a few years became world-famous, with nearly 1,000 members and branches in Australia, the Isle of Man and Pernambuco. Presidents included men such as T. G. Elger, of lunar fame, and Dr Isaac Roberts, celebrated for his fine photographs of nebulæ. Brashear wrote: 'I should esteem it a very great honour to belong to such a vigorous working Society', and members and associate members included men of the calibre of Prebendary Webb, Calver, Denning, Gore, Ball, Schiaparelli, Sir Howard Grubb, Wassell, Newall, Asaph Hall, Agnes M. Clerke, Arthur Mee, Otto Struve, Piazzi Smyth, etc., not forgetting, in 1887, His Imperial Majesty the Emperor of Brazil.

At the suggestion of Elger, then President, the Annual General Meeting was held at the Royal Astronomical Society's rooms in Burlington House, in view of the national character which the Society had assumed, and there was a proposition that ordinary meetings should be held in different towns and cities. Educational classes were started in Liverpool, Douglas and other branches, and certificates of competency issued. Observing sections, with directors, included lunar, double star, variable star, star colour, solar, Jupiter, Saturn, meteor, and comet-seeking.

By 1889 hundreds of copies of the monthly journal were being sent all over the world, and *The Observatory* advertised in the monthly journal, printing the reports of the R.A.S. and also the

Liverpool Astronomical Society. Then Fate stepped in, and this colossus of a Society burst like a supernova, so that the British Astronomical Association was formed from the fragments. What happened is difficult to trace, but from a study of contemporary newspapers, minute-books, etc., it seems to be as follows:

The crisis arose through the discovery that the finances of the Society were in a chaotic state, large sums being due to the printers. The Treasurer resigned, the reigning President died and the Secretary fell ill. In the meanwhile, Maunder was pressing for the foundation of a similar society based in London, and at a London meeting the BAA was formed with the same sections, and section leaders lifted *en bloc* from the temporarily paralysed Liverpool Society. With the aid of a substantial sum of money donated, the BAA flourished and carried on the work formerly done by the LAS, which became a local society. The local members cleared off all the debts left behind by the departed corps of writers, and proceeded to set what may be another record in that W. E. Plummer, Director of Liverpool Observatory, was elected President in 1892 and held office until 1919.

Activities were restricted during the two world wars, and after the second war regular meetings were not resumed until A. C. Sanderson volunteered to act as Secretary and started a publicity campaign to attract new members. The Society's large Cooke equatorial telescope, mounted in a 15-foot, revolving dome, had been lying in a derelict state since the first war, so the job of reconditioning it was completed, and after consultation with the local education authorities weekly meetings were started at the Observatory. Monthly lectures were arranged at the Royal Institution, where the Society's library and slides are housed. Once a year 600 Merseyside sixth-formers are invited to hear a famous lecturer in the main hall of the Royal Institution, and consequently the Society has a strong junior section. Telescopes, slides, a celestial camera, and library books are available to members, who pay an annual subscription of 15*s*; the junior subscription is 5*s*. The Secretary is J. E. Abrahams, 135 St Michael's Road, Great Crosby, Liverpool 23.

We are a happy Society, and our guiding rule is that laid down at the inception of the Society in 1881, namely: To be a help to the possessors of small telescopes, and a guidance to those interested in the science of astronomy. – *A. C. Sanderson.*

THE MAIDENHEAD ASTRONOMY GROUP

Membership of the Group stands at 17. The annual subscription is 10*s* for senior members, and 2*s* 6*d* for those aged under 18. We meet at three-weekly intervals at the Maidenhead Grammar School, Shoppenhangers Road, Maidenhead. The Chairman is S. Stroud, 129 Fane Way, Maidenhead; the 1965 Secretary is S. A. H. Roper, 46 Pinkneys Road, Maidenhead. The Group is affiliated to the BAA. Apart from winter meetings, in the summer we have outings to places of both astronomical and general scientific interest. – *E. H. Bailey.*

THE MANCHESTER ASTRONOMICAL SOCIETY

The Society, which celebrates its Diamond Jubilee this year, has approximately 150 members, who meet weekly at the headquarters—the Godlee Observatory, Manchester 1. The Observatory has available an 8-inch refractor and a 12-inch reflector. Lectures are held in the Reynolds Hall of the College, monthly from October to April inclusive. A quarterly journal, *Current Notes*, is issued to members. The Society is very actively engaged in collaboration with the BAA programmes of solar, lunar, planetary and auroral observation. A large library is available, housed partly in the Observatory and partly in the Manchester Central Library. Subscriptions: £1 per year (juniors 10*s*); entrance fee 7*s* 6*d*. Present officers are: President, S. W. H. Mottram, AMCT, FRAS; Secretary, Alan Whittaker; assistant secretary, J. D. Ettenfield. All inquiries should be sent to Alan Whittaker, Cragside, Cliff Avenue, Summerseat, Bury, Lancashire. – *A. Whittaker.*

THE NEWCASTLE-UPON-TYNE ASTRONOMICAL SOCIETY

The Society, formed in January 1904, celebrated its Diamond Jubilee in 1964. Meetings are held once a month during the

session September to April, usually at the Botany Lecture Theatre at the University of Newcastle. Sometimes, for special meetings or public lectures, the Society is allowed the use of one of the larger lecture theatres in the Physics Department. The President is G. M. Sisson; the Secretary, G. E. Manville, 30 Kew Gardens, Whitley Bay, Northumberland. – *G. E. Manville.*

THE NORWICH ASTRONOMICAL SOCIETY

The Society was formed as a small group in 1945, and was enlarged in 1953, now having a membership of 40. Members built their own observatory on the outskirts of Norwich in 1955. This houses a 10¼-inch reflector, with a mirror figured by H. E. Dall. An adjoining building provides a club-room, and gatherings are held there on two or three nights a week throughout the year. The telescope is always available by arrangement, and is open to the public on most Saturday evenings. Monthly meetings are held in the Assembly House, Theatre Street, from September to April. Special observing parties are catered for, and these have included many from local schools and clubs, it being the Society's main intention to interest young people. Activities among the members include telescope- and mirror-making and astronomical photography. Several members have their own instruments. All inquiries should be sent to W. E. Bennett, 68 Clarendon Road, Norwich. – *W. E. Bennett.*

THE OXSHOTT ASTRONOMICAL GROUP

Meetings are held at the Oxshott Village Centre, Holtwood Road, Oxshott, on the first Wednesday of the month (September to May). The observatory has a 10-inch equatorial reflector, and facilities are available for lunar photography. The membership is 30, and the annual subscription 10*s.*

The main object of the Group is to cater for beginners by means of a tutorial course. This is devised to encourage personal observation, stimulate inquiry and organize co-operative effort. The secondary object is to give guidance to those whose main desire is to obtain a broad picture of the universe as conceived today.

All inquiries should be addressed to E. H. Noon, Norman Cottage, Pond Piece, Sheath Lane, Oxshott, Surrey. – *E. H. Noon.*

THE PRESTON AND DISTRICT ASTRONOMICAL SOCIETY

The Society holds lecture meetings on the third Monday of each month from September to May inclusive at the Chamber of Commerce, 49A Fishergate, Preston, at 7.30 p.m. An excellent selection of lecturers from northern universities and societies provides information talks on all aspects of astronomy. A popular film show is held annually.

Members have the use of the 8-inch refractor at the Jeremiah Horrocks Observatory, Preston, on the remaining Mondays of each month.

The Society is constructing a new observatory at Longridge, near Preston, for the use of members at any time by permission of the Director.

The journal is published quarterly, and is free to members. There is a Library service available at small extra cost, and subscribers receive magazines and books on a rota basis. Social activities include an annual dinner, a star-party, visits to places of scientific interest, and meetings with other Societies.

Membership fee, £1 (for those aged under 18, fee 5*s*), associate membership for those living over 30 miles from Preston, 5*s* (including copies of the Journal).

There is an arrangement that members may also attend all meetings of the East Lancashire Society. All inquiries should be sent to C. Lynch, 51 Bispham Road, Carleton, Poulton-le-Fylde, Lancashire. – *C. Lynch.*

THE SLOUGH ASTRONOMICAL SOCIETY

The Society was founded some 15 years ago, and has been meeting regularly during the winter months ever since. We now have about 60 members, and meetings are arranged monthly, usually in the form of a talk given by a visiting lecturer.

Some of our members have telescopes of their own, in the 6-

inch to 8-inch reflector class, constructed by themselves. The Society owns a 12-inch reflector and observatory, but we regret to say that this has never been used by us, since up to the present time it has been impossible to find a permanent site or to get permission to erect the observatory anywhere in the area.

Membership is open to all. All inquiries should be sent to E. Shilton, The Elms, Odds Farm, Green Common Lane, Wooburn Common, High Wycombe, Buckinghamshire. – *E. Shilton.*

THE SOUTHAMPTON ASTRONOMICAL SOCIETY

The Society has a membership of 40. The subscription is £1 per annum (10*s* for members aged under 21); meetings are held on the second Thursday in the month, September to May inclusive, at the Polygon Hotel, Southampton. All inquiries should be sent to F. G. H. Cunningham, 13 Luccombe Place, Shirley, Southampton. – *F. G. H. Cunningham.*

THE STOKE-ON-TRENT ASTRONOMICAL SOCIETY

The Society was founded in 1957, and at present has some 25 active members, many of whom are keen observers. Meetings are held monthly in Hanley, and usually consist of a talk given by a member followed by a general discussion. A wide range of subjects is covered, from telescope mountings to relativity and cosmology. We have as our President, Dr J. N. Hodgson, of the Physics Department of Keele University, and through him we have access to the facilities of the Physics Department, as well as the University's telescope, a 12-inch refractor, formerly at the Oxford University Observatory.

Many members possess their own telescopes, and at least two have more elaborate observatories under construction. As is to be expected, almost all serious observation is confined to lunar and planetary objects. Of particular interest in this respect are the drawings of B. Doherty and his son Paul, of the Moon and the planets Jupiter and Saturn. Several of these drawings have appeared in BAA publications and elsewhere.

In spite of the obvious and increasing interest in astronomy,

we seem to be unable to increase our membership substantially, despite the fact that the area is well populated. We do, however, feel that societies such as ours fill a need which reading and private observation cannot alone supply, in that meeting people of like interests stimulates a greater awareness of the scope of astronomy. All inquiries should be sent to T. F. Stringer, 19 Englesea Avenue, Weston Coyney, Stoke-on-Trent. – *T. F. Stringer.*

THE SWANSEA ASTRONOMICAL SOCIETY

The Society was formed in 1948, and with the help of Gordon Taylor (now of Herstmonceux) we started lantern lectures. Later we had several 3-inch refractors to help with observation evenings.

The Society set about building an observatory, and after many efforts established a 12-foot dome housing a 9-inch Newtonian reflector. The setting-up of the instrument was most interesting, and subsequently observing nights were organized. A start was made in astronomical photography, with good results; see, for instance, some of the photographs in Patrick Moore's book *The Amateur Astronomer.*

The Society still meets, but with reduced numbers, now that some of the older members have had to retire from active observing. However, new younger members are available from local schools, and at the moment we are rebuilding the Society membership. All inquiries should be sent to R. E. Roberts, 77 Graiglwyd Road, Cockett, Swansea. – *R. E. Roberts.*

THE TORBAY ASTRONOMICAL SOCIETY

The Torbay Astronomical Society was founded in May 1956. It was the intention to provide a common meeting-ground for people interested in all aspects of astronomy. Lectures and film shows are arranged monthly during the winter, and members have ample opportunity to discuss and learn the rudiments of astronomy. It includes in its membership people from the South Devon area, and due to popular request a branch society has recently been formed in Exeter.

Telescopes available for use by members include 12-inch and

10½-inch reflectors and 3½-inch and 3-inch refractors. At the moment we are considering the possibility of establishing our own observatory. There is a lending library available, and lectures on an exchange basis are arranged with the Bristol Astronomical Society. At the moment we have a membership of 35. The annual subscription is 15*s* for senior members and 5*s* for juniors. Meetings this session are held at Quay Tor Hotel, Scarborough Road, Torquay. The Chairman is G. C. Jones, Quay Tor Hotel, Scarborough Road, Torquay; the Secretary of the Exeter branch is G. R. Aspin, 1 St Mary's Steps Terrace, Exeter. Inquires should be sent to Miss Avril Longman, 4 Heath Rise, Brixham, Devon. – *Avril Longman.*

THE WARWICKSHIRE ASTRONOMICAL SOCIETY

The Warwickshire Astronomical Society was formed in 1959. Its aim is to provide a friendly focal point for all those with an interest in astronomy.

The Society Headquarters is located at 20 Humber Road, Coventry, which consists of a club-room and workshop facilities for those wishing to make their own telescopes. A library, supplies of carborundum, pitch, etc., for mirror grinding, and apparatus are available for free use by members.

A meeting takes place every Tuesday at 7.30 p.m., but the premises are available 7 days a week to any member wishing to use them.

Cosmos, the Society's official journal, is published monthly, and is free to members. Lectures, film shows and special functions are arranged from time to time. Annual membership is open to all with an interest in astronomy; the subscription is £4.

A recent addition to the Society's assets is a 10-inch Newtonian reflector, to be sited, when land is available, on the outskirts of Coventry. All inquiries should be sent to R. D. Wood, 20 Humber Road, Coventry. – *R. D. Wood.*

THE WOLVERHAMPTON ASTRONOMICAL SOCIETY

The Society was established in 1950, and has at present 60

members. Meetings are held every other Monday from September to April at the Committee Room, 38 Tettenhall Road, Wolverhampton.

The Society maintains a library of some 100 books, and has an excellent collection of slides and photographs. It also possesses 9-inch and 6-inch reflectors, and others are in use or under construction by individual members. Visiting lecturers are invited to give talks on a wide range of topics dealing with astronomy and associated subjects.

The aim is to cater for the beginner as well as the experienced amateur, and a free exchange of ideas is encouraged. From time to time visits to various establishments are arranged. Exhibitions have recently been staged with considerable success, and the group is widening its sphere of influence in the district. The Society is affiliated to the BAA, and several members are also members of that organization. All inquiries should be sent to M. Astley, Garwick, 8 Holme Mill, Fordhouses, Wolverhampton. – *M. Astley.*

THE YORK ASTRONOMICAL SOCIETY

The York Astronomical Society was formed in the spring of 1961, and numbers about 25 members. The session lasts from September to May inclusive, during which time meetings are held each month. These meetings comprise lectures, demonstrations, film shows, etc., given by outside speakers and members of the Society. A library is kept, and books, periodicals and abstracts may be borrowed at each monthly meeting.

The Society runs a Telescope and Instrument Group, and a 4-inch reflector has been completed. The group is working on a larger mirror, and is also engaged in the restoration of a 4-inch Cooke refractor, which was obtained recently from a private observatory by the generosity of a local school. The instrument is complete with pillar, driving clock and accessories.

An observation group has also been formed, and a suitable programme worked out, but the Society is having difficulty in securing a site in York from which regular observations may be

carried out. Negotiations are proceeding, but the wheels of officialdom grind very slowly! The Chairman for the present session is M. C. Metcalfe; R. Emmerson, 97 Carr Lane, Acomb, York, is Secretary.

Annual fees are £1 for members and 5*s* for students. Further details may be obtained from the Secretary. – *M. E. Metcalfe.*

Some Recommended Books

Nebulae and Galaxies, by G. Abetti and M. Hack. (Faber & Faber, London, 1964.) A semi-technical account, but non-mathematical and therefore intelligible to the layman who has a little previous knowledge. Strongly recommended.

Pictorial Guide to the Moon, by D. Alter. (Arthur Barker, London, 1964.) A general account of the Moon, with many photographs of lunar details.

The Sun and the Planets, by G. Fielder. (Harrap, London, 1964.) A book for the 10 to 12 age-group, very clearly and skilfully written.

Watchers of the Skies, by W. Ley. (Sidgwick & Jackson, London, 1964.) An outstandingly good history of astronomy, easy to read and yet providing a tremendous amount of information.

Astronomy, by Patrick Moore. (Oldbourne Book Co., London, 1964.) The second edition of this book, brought up to date since the original edition of 1961.

Astronomy with Binoculars, by J. Muirden. (Faber & Faber, London, 1964.) A guide to sky-watchers who have the most modest optical equipment.

The Nature of Comets, by N. B. Richter. (Methuen, London, 1964.) An easy-to-read, non-mathematical but semi-technical book, well translated from the original written by a leading astronomer of East Germany.

The Astronomers, by C. A. Ronan. (Evans Bros., London, 1964.) An excellent non-technical book, consisting of biographies of famous astronomers from Pythagoras to Einstein. Highly recommended.

The Flammarion Book of Astronomy. (Allen & Unwin, London, 1964.) A large, lavishly-illustrated book; the latest edition of the Flammarion classic, brought up to date and largely re-written. It costs £5, but is excellent value.

Yearbook of Astronomy 1965

Editor Patrick Moore

This yearbook has been specially designed for the amateur astronomer and, once again, the new edition has been completely revised. The notes and data have been brought up to date for 1965 and a new series of articles included.

Dr Porter has been unable to continue editing this series but has again contributed the star charts and monthly notes. Patrick Moore, who has been associated with the *Yearbook* since its inception, has taken over the position of editor as well as contributing his usual article on recent advances in astronomy.

The *Yearbook* is of great value to all interested in astronomy and particularly to the amateur who likes to look out for the planets and various astronomical events. A cycle of clusters and galaxies suitable for observation with the naked eye or a small telescope is included for the first time and there is a full list of societies that the amateur astronomer can join.

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